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IDENTIFICATION AND EVALUATION OF FLUVIAL-DOMINATED DELTAIC (CLASS I OIL) RESERVOIRS IN OKLAHOMA

Final Report
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By
Mary K. Banken

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Oklahoma Geological Survey
University of Oklahoma
Norman, Oklahoma

National Petroleum Technology Office
U. S. DEPARTMENT OF ENERGY
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I. ABSTRACT

The Oklahoma Geological Survey (OGS), the Geo Information Systems department, and the School of Petroleum and Geological Engineering at the University of Oklahoma have engaged in a five-year program to identify and address Oklahoma's oil recovery opportunities in fluvial-dominated deltaic (FDD) reservoirs. This program included a systematic and comprehensive collection and evaluation of information on all FDD oil reservoirs in Oklahoma and the recovery technologies that have been (or could be) applied to those reservoirs with commercial success.

The execution of this project was approached in phases. The first phase began in January, 1993 and consisted of planning, play identification and analysis, data acquisition, database development, and computer systems design. By the middle of 1994, many of these tasks were completed or nearly finished including the identification of all FDD reservoirs in Oklahoma, data collection, and defining play boundaries. By early 1995, a preliminary workshop schedule had been developed for project implementation and technology transfer activities. Later in 1995, the play workshop and publication series was initiated with the Morrow and the Booch plays. Concurrent with the initiation of the workshop series was the opening of a computer user lab that was developed for use by the petroleum industry. Industry response to the facility initially was slow, but after the first year lab usage began to increase and is sustaining. The remaining six play workshops were completed through 1996 and 1997, with the project ending on December 31, 1997. The play workshop and publication listing (in order of production) was as follows: Morrow, Booch, Layton and Osage-Layton, Prue and Skinner, Cleveland and Peru, Red Fork, Tonkawa, and Bartlesville.

This program has been described by numerous industry representatives as the most valuable program that the Oklahoma Geological Survey has ever implemented. Since there is no direct way to measure the impact that this program has had on the volumes of FDD oil production in Oklahoma, the success of the program must be measured in terms of the accomplishments and the industry evaluations of those accomplishments. Eight highly successful workshops and accompanying publications were completed on eleven FDD horizons. A computer user laboratory was established and continues to be a resource to the industry. Industry relationships with the project participants have shown vast improvements. Industry feedback to the program has been overwhelmingly positive. The development of this FDD program and the support of the U.S. Department of Energy have set the stage for a strong technology transfer foundation for Oklahoma's petroleum industry.

III. EXECUTIVE SUMMARY

The Oklahoma Geological Survey (OGS), the Geo Information Systems department, and the School of Petroleum and Geological Engineering at the University of Oklahoma engaged in a five-year program to identify and address Oklahoma's oil recovery opportunities in fluvial-dominated deltaic (FDD) reservoirs. This program included a systematic and comprehensive collection and evaluation of information on all FDD oil reservoirs in Oklahoma and the recovery technologies that have been (or could be) applied to those reservoirs successfully. This data collection and evaluation effort was the foundation for an aggressive, multifaceted technology transfer program that was designed to support all of Oklahoma's oil industry. However, particular emphasis of this program was directed toward smaller companies and independent operators in order to help them maximize oil production from FDD reservoirs.

Specifically, this project identified all FDD oil reservoirs in the State; grouped those reservoirs into plays that have similar depositional and geologic histories; collected, organized and analyzed all available data; performed characterization and simulation studies on selected reservoirs in each play; and implemented a technology transfer program that targeted operators of FDD reservoirs. These elements of the FDD program provided the kind of assistance that could allow operators to extend the life of existing wells with the ultimate objective of recovering more oil.

The execution of this project was approached in phases. The first phase began in January, 1993 and consisted of planning, play identification and analysis, data acquisition, database development, and computer systems design. By the middle of 1994, many of these tasks were completed or nearly finished including the identification of all FDD reservoirs in Oklahoma, data collection, and defining play boundaries. Later in 1994, a preliminary workshop schedule was developed for project implementation and technology transfer activities. In early 1995, a specific workshop agenda was formatted and play publication requirements were identified. Later in 1995, the play workshop and publication series was initiated with the Morrow play in June and the Booch play in September. The remaining six play workshops were completed through 1996 and 1997, with the project ending on December 31, 1997.

The following is a summary of tasks completed as part of the implementation and technology transfer activities of this FDD project:

Task 1: Database and Applications Development: Computer support activities included ongoing database development and maintenance, applications development, and user lab development and operation. An operator database was designed to track operators (and other interested parties) who were working with FDD reservoirs in Oklahoma. These operators were targeted to participate in the data collection process as well as the technology transfer program. A variety of computer applications programs were developed for data analysis, for publication and workshop preparation, and to support users. Computerized mapping and report programs were necessary for reservoir analysis and regional play interpretations. Database development also involved reformatting *NRIS* well, lease and field mainframe databases for p.c.-level access through a computer user lab, which was one of the primary technology transfer tools implemented during this project. The lab was opened on June 1, 1995, in conjunction with the Morrow play presentation. Industry response to the facility initially was slow, but after the first year lab usage began to increase and is sustaining.

Task 2: Play Analyses, Publications, and Workshops: During the project, eight FDD workshops involving 11 plays with accompanying folio publications were completed.

The Morrow Play was the first in the series, presented on June 1 and 2, 1995 at the Sarkeys Energy Center in Norman, Oklahoma. A total of 215 people attended either day. Morrow fluvial systems are found principally in three regions within Oklahoma: the Dewey-Blaine Counties embayment, the Woodward "trench", and the Panhandle region comprising of Texas, western Beaver, and eastern Cimarron Counties. Detailed information was provided for three Morrow field studies: the Canton field area in Dewey County, the South Balko field in Beaver County, and the Northeast Rice field in Texas County. A reservoir characterization and waterflood simulation study was completed and presented for the Northeast Rice field.

The Booch Play was presented next, on September 11, 1995 at the Indian Capital Vo-Tech School in Muskogee, Oklahoma. A total of 128 people attended that workshop. The Pennsylvanian sandstones in the Booch were significant oil reservoirs during the early history of the oil industry in Oklahoma; Booch reservoirs are still important today for potential recovery of additional oil by water-flooding or other enhanced recovery methods. The Booch play is located on the Cherokee Platform in northeastern Oklahoma and extends southward beyond the hinge line of the McAlester Formation into the Arkoma basin. Detailed information was provided for two Booch field studies: the Northwest Wewoka field area in Seminole County, and the Greasy Creek field in Hughes County. Additionally, a reservoir characterization and waterflood simulation study was completed and presented for the Greasy Creek field.

The Layton and Osage Layton play was presented on April 17, 1996 at the Francis Tuttle Vo-Tech Center in Oklahoma City. It was well attended by 103 people. The Layton and Osage Layton sands constitute two different zones or formations (the Layton lies 100 ft or more below the Osage-Layton). The names have been so misused by industry, that it is nearly impossible to differentiate between the two reservoirs from production records or from formation tops recorded on completion reports. This problem was addressed in the workshop but because it is so widespread, both formations were treated as one play in the regional discussion. Detailed geologic field studies within this workshop and play publication include the East Lake Blackwell and South Coyle fields. East Lake Blackwell field is an Osage-Layton sand reservoir that also was used in the waterflood simulation study. South Coyle field is a Layton sand reservoir that lies stratigraphically below the Osage-Layton interval.

The Prue and Skinner plays were presented on June 19 and 20, 1996 in Oklahoma City, and on June 26, 1996 in Bartlesville. Because of the large number of operators and high interest in these plays, three workshops were necessary to accommodate the 201 attendees. Similarities in depositional origin, stratigraphy, age, and environments of deposition made it convenient to group the Prue and Skinner plays into one workshop. Major topics included in the publication and workshop consisted of the regional analysis of each play along with three Skinner field studies and one Prue field study. The four fields have diverse geologic characteristics that typify many of the clastic reservoirs in the Cherokee Platform of eastern Oklahoma. Two of the fields have already been water flooded which provided a good analogy for this technology. Enhanced recovery simulation studies were completed on one Prue and one Skinner reservoir. Computer modeling utilized software demonstrated in previous workshops (Eclipse) in addition to Boast III which is more widely available to the public.

The Cleveland and Peru workshop was completed October 17, 1996 in Bartlesville, Oklahoma with 85 attendees. Each play was presented individually using the adopted protocol of stratigraphic interpretations, a regional overview, and detailed field studies. Two field studies were completed including the Pleasant Mound Cleveland oil pool and the Hogshooter Peru oil pool. A waterflood simulation was completed for the Pleasant Mount Cleveland oil pool. The Peru field study was not considered suitable for waterflood simulation because of the lack of production data. Instead, a guest lecturer presented a talk on formation evaluation of the Peru sand in the Hogshooter oil field.

The Red Fork Play was the subject of a workshop that was presented twice: on March 5, 1997 in Norman, and again on March 12 in Bartlesville, to a total of 195 attendees. The Red Fork sandstone has been, and continues to be, one of the main producers of oil and gas in Oklahoma, as well as one of the most widespread Cherokee plays in Oklahoma. The Red Fork interval extends from the Cherokee platform, across the Nemaha fault zone and the central Oklahoma uplift to the Anadarko basin. Field studies were completed on the North Carmen Field in Alfalfa County and the Long Branch Field, located in east-central Payne County. This is the same field area in which a Prue reservoir had been the subject of a previous study and workshop.

The Tonkawa Play has been of continued interest for many operators and geologists for a long time, but recently has become very active in western Oklahoma. The renewed interest in the Tonkawa centers in the Anadarko Shelf and Basin areas where production is prone to gas from marine sands. Because of this high interest, the Tonkawa FDD workshop was partnered with a presentation on the Tonkawa gas play. The workshop was presented on July 9, 1997 in Norman with 101 attendees. Portions of north central Oklahoma have significant areas containing FDD deposits, but only scattered areas within the FDD portion of the play produce oil. The Virgilian age sandstones of the Tonkawa play are the youngest of the fluvial-deltaic reservoirs to be investigated in the FDD workshops, with drilling depths of about 2,200-4,400 ft. A field study was completed on the Blackwell Field in Kay.

The finale of the FDD program was the Bartlesville Play. Oil reservoirs in the Bartlesville sandstone were the foundation for the dominance of Oklahoma as an oil producing state, beginning with the No. 1 Nellie Johnstone in 1897. This workshop was presented three times and locations: on October 29, 1997 in Tulsa, on October 30 in Bartlesville, and on November 12, 1997 in Norman. Attendance for the three sessions totaled 183. The Bartlesville play is situated on the Cherokee platform of northeastern Oklahoma. Bartlesville field studies included the Paradise field in Payne County and the Northwest Russell field in Logan County.

Since the inception of the workshop program in 1995, industry responses to the program have been very positive. In short, this program has been described by numerous industry representatives as the most valuable program that the Oklahoma Geological Survey has ever implemented. The operator registration statistics for the various workshops support this assertion. There were 1,211 total workshop registrations in the program, reflect 584 individuals, many with multiple registrations. Of the 584 individuals, 355 (61%) are from active operating companies, based on a comparison of company names to gross production tax records, and 145 (25%) are from other industry interests such as service companies, or are "consultants"(31) or "independents"(30), that could not be linked to the gross production tax records.

Task 3: Professional Outreach: Three levels of professional outreach have been identified as part of this overall project effort. The first, technical advising, refers to those industry contacts that take place as follow-ups to the workshop presentations. Second, the ongoing reservoir characterization and simulation studies provide opportunities for individualized efforts with operators. Third, professional activities such as conferences provide a forum for promoting the FDD program activities.

CONCLUSIONS

There is no direct way to measure the impact that this program has had on the volumes of FDD oil production in Oklahoma. Throughout Oklahoma, as in the rest of the domestic petroleum industry, oil well abandonments have continued to increase and production has continued to decline throughout the five years of the program. There is no way of knowing what that decline would have been if this program had not been implemented. Furthermore, most of the volumetric impacts of this program will in fact be realized in future years. If this program has served its function, it will be demonstrated through the ongoing viability of FDD reservoirs five to ten years in the future.

Since volumetric measures cannot be provided, the success of the program must be measured in terms of the accomplishments and the industry evaluations of those accomplishments. Eight highly successful workshops and accompanying publications were completed on eleven FDD horizons. A computer user laboratory was established and continues to be a resource to the industry. Industry relationships with the project participants have shown vast improvements. Industry feedback to the program has been overwhelmingly positive.

Numerous operators and industry people provided positive feedback for the overall program. Due to the nature of the Oklahoma FDD project, it is recognized as one of the most successful and respected programs to assist operators throughout the entire Mid-Continent region. Nearly everyone wants this program continued or expanded. Because of this, arrangements have been made with the Oklahoma City Geological Society to present "repeat"workshops of some of the workshops, and requests for copies of the play publications continue to be received. Furthermore, the Oklahoma Geological Survey has plans to continue with the "play analysis"format as a permanent component of their overall program. The development of this FDD program and the support of the U.S. Department of Energy have set the stage for a strong technology transfer foundation for Oklahoma's petroleum industry.

IV. INTRODUCTION

The Oklahoma Geological Survey (OGS), the Geo Information Systems department, and the School of Petroleum and Geological Engineering at the University of Oklahoma engaged in a five-year program to identify and address Oklahoma's oil recovery opportunities in fluvial-dominated deltaic (FDD) reservoirs. This program included the systematic and comprehensive collection and evaluation of information on all of Oklahoma's FDD oil reservoirs and the recovery technologies that have been (or could be) applied to those reservoirs with commercial success. This data collection and evaluation effort was the foundation for an aggressive, multifaceted technology transfer program that was designed to support all of Oklahoma's oil industry. However, particular emphasis of this program was directed at smaller companies and independent operators in order to help them maximize oil production from FDD reservoirs.

Project efforts included identifying all FDD oil reservoirs in the state; grouping those reservoirs into plays with similar depositional and geologic histories; collecting, organizing and analyzing all available data; conducting characterization and simulation studies on selected reservoirs; and implementing a technology transfer program that targeted operators of FDD reservoirs.

The elements of the technology transfer program included developing and publishing play summaries in the form of folios, holding workshops to release play analyses and discuss opportunities in each of the plays, and establishing a public-access computer user laboratory within the OGS. The user lab contained all the play data, as well as other oil and gas data files, together with the necessary hardware and software to analyze the information. Technical support staff were available to assist interested operators in the evaluation of their producing properties, and professional geological and engineering outreach staff were available to help determine appropriate recovery technologies for those properties.

The FDD project assisted numerous operators in Oklahoma by providing them with practical ways to improve production from existing leases and/or to reduce operating costs. Currently-available technologies can improve recovery factors in these FDD reservoirs when sufficient information is available to determine the most appropriate course of action for an operator. This project developed the needed reservoir-level information and worked with interested operators in the implementation of the appropriate improved recovery technologies.

Light oil production from Class I Oil fluvial-dominated deltaic reservoirs is a major component of Oklahoma's total crude oil output. These types of reservoirs provide approximately 15 percent of the State's total oil production. Most of this production is by small companies and independent operators. This segment of Oklahoma's oil industry typically does not have ready access to the information and technology required to maximize the exploitation of these reservoirs.

Oil production from FDD reservoirs is at high risk. Individual well production is often very low (one to three barrels per day) and operating costs continue to rise. These factors, in addition to cyclic crude oil prices, resulted in oil well abandonment rates that have more than doubled in recent years. Successful implementation of appropriate recovery technologies and field development practices could help to sustain production from these reservoirs throughout much of the 21st century. Without such action, most oil production from Oklahoma FDD reservoirs will be abandoned by the beginning of the next century.

V. DISCUSSION

The execution of this project was approached in three phases. *Phase 1* began in January, 1993 and consisted of planning, play identification and analysis, data acquisition, database development, and systems design. By the middle of 1994, many of these tasks were completed or nearly finished including the identification of all FDD reservoirs in Oklahoma, data collection, and the definition of play boundaries. Later in 1994, a preliminary workshop schedule was developed for the implementation and technology transfer activities of *Phases 2 and 3,* respectively. In early 1995, a specific workshop agenda was developed and folio publication requirements were identified. Later that year, the Morrow and Booch workshops were completed along with the accompanying folio publications. During 1996, three more workshops were completed involving six separate plays. These were the Layton and Osage-Layton, the Prue and Skinner, and the Cleveland and Peru plays. By this time, the workshop format had evolved to include better organization of data, more information, and better allocation of time for presentations and demonstrations. During the final year of the program, workshops and publications were completed for the Red Fork, the Tonkawa, and the Bartlesville plays.

The following sections briefly describe technical activities relating to the tasks of this project.

Task 1: Database and Applications Development

Technical computer database development activities were divided into three primary tasks:

1) Database Development and Maintenance. This activity included efforts to develop and upgrade FDD databases and to capture the information gathered during this project. Database development also involved reformatting *NRIS* well, lease and field mainframe databases for p.c.-level access through a computer user lab.

Initially, three databases were developed for this project. A reservoir database was designed to record reservoir characteristics, engineering, and production data for each identified FDD oil reservoir in Oklahoma. A bibliographic database was designed to track the reference information related to the Oklahoma FDD reservoir research. For the early plays, considerable effort was devoted to gathering and coding information to enter into these databases. However, after the first year of workshops and publications it became clear that the demand for these databases, and the value achieved from them, did not warrant the level of effort required to maintain them. Project staff efforts were utilized much more effectively to prepare the publication and workshop materials. Thus, the maintenance of these two databases became a lower priority for the overall project.

In contrast, the operator database was a fundamental tool throughout the entire project. The operator database was designed to track operators (and other interested parties) who were working with FDD reservoirs in Oklahoma. These operators were targeted to participate in the data collection process as well as the technology transfer program. The operator database originally was developed at the mainframe level, but work was completed during the program to convert the operator file to the personal computer to allow tracking participation in various activities of this project, and help measure the overall effectiveness of the technology transfer program. That conversion was completed prior to the Morrow workshop held in June, 1995.

Operator mailouts, registrations, and summary data in this report were made possible though this database.

One fundamental precursor to the analysis of FDD reservoirs was the appropriate delineation of the oil field boundaries in which these reservoirs occur. Project staff worked with the Oklahoma Nomenclature Committee (ONC) of the Mid-Continent Oil & Gas Association to identify updates to the official field boundaries based on field and lease data from the Natural Resources Information System (*NRIS*)

2) Applications Development. A variety of computer applications programs were required for data analysis, for publication and workshop preparation, and to support users. Many of these programs were standardized for repeated applications in the various plays. These programs were mostly developed prior to 1995 as part of the *Phase 1* planning and analysis, but were modified and enhanced during subsequent years to prepare for new plays. Computerized mapping and report programs were necessary for reservoir analysis and regional play interpretations. These included programs to generate standard reports and tables, perform statistical analyses, generate graphical displays of the data, and produce surface and subsurface maps. The outputs from some of these programs were incorporated into the play folio publications and/or used as exhibits during the play workshops. At the mainframe level, commercial software systems such as SAS (Statistical Analysis System) were used for most of the applications, editing, and data manipulation. At the personal computer level, applications are based on a variety of commercial packages. Mapping was completed through application programs such as Arc/Info and ARCVIEW, GeoGraphix and Easycad.

3) User Lab Development and Operation. One of the primary technology transfer tools implemented during this project was a computer user laboratory. The user laboratory was developed as one mechanism for allowing industry, especially small independents, to access the resources developed as part of this project. Capabilities of the laboratory were supplemented through software and support provided by the Petroleum Technology Transfer Council program. Housed within the offices of the Oklahoma Geological Survey, and staffed with technical advisors who can assist users in developing their own applications, the computer user laboratory is advantageous for those who have little or no experience using computerized resources for their decision-making.

User lab development activities included both the acquisition of hardware and software, and the development of user interfaces for the data and software applications that are available through the user lab. Currently, the computer facility is equipped with 4 Pentium microprocessors, a laser printer and E-size plotter, and a scanner on a Novell network. User lab software includes both commercial and public domain packages, since a technology transfer goal of the user lab is to provide examples of applications that operators might want to adopt for their own use. The in-house software development that was completed for the project was primarily for site-specific activities such as developing user interfaces and user lab accounting processes. Standard word processing, spreadsheet, project management and graphics packages are all available. Geologic mapping is possible through application programs such as GeoGraphix contouring package, and spatial analyses will be possible through Arc/Info and ARCVIEW.

In late 1994 a decision was made to use an Oracle database engine with Visual Basic programming language to develop the user interfaces. The actual installation of Oracle took place in early 1995 after the network software was upgraded to Novell Netware 3.12. Efforts then were initiated to develop the Visual Basic interfaces to allow easy access to the *NRIS* and FDD data.

The lab was opened on June 1, 1995, in conjunction with the Morrow play presentation. Industry response to the facility initially was slow, primarily due to the lack of visibility for the facility and difficulty accessing the facility on campus. During the first year of operation, the lab averaged four users and 50 hours of usage per month. After the first year, the lab was moved to a more accessible location on the north side of Norman, and lab usage began to increase to an average of 11.5 visitors and 196 usage hours per month during the second year. This usage level is sustaining, and despite the close of this FDD project, the lab operation is continuing through the support of the Petroleum Technology Transfer Council.

Task 2: Play Analyses, Publications, and Workshops

The concept of a "play" is used to describe reservoirs that are subject to petroleum exploration or development. For the purposes of this project, the plays were characterized by a geologic formation or horizon that contains FDD reservoirs. In Oklahoma, all of the FDD oil reservoirs are Pennsylvanian in age. A list of Oklahoma's FDD oil reservoirs, in order of geologic age from youngest to oldest, is summarized in Table 1. These reservoirs were grouped into plays and delineated on regional sand trend maps that showed play boundaries and regional depositional environments.

TABLE 1 - FLUVIAL-DOMINATED DELTAIC OIL RESERVOIRS: OKLAHOMA PLAYS

PLAY	Reservoirs	Location	Class*	Leader	Comments
1. Tonkawa Play (Virgilian)	Tonkawa sd	NE Oklahoma Platform Nemaha Uplift NW Anadarko Shelf	B	Campbell	Workshop completed 7/97
2. Layton & Osage-Layton Plays (Upper Missourian)	Osage-Layton sd "True" Layton	NE Oklahoma Platform Nemaha Uplift NE Flank Anadarko Basin	B	Campbell	Workshop completed 4/96
3. Cleveland Play (Lower Missourian)	Cleveland sd	NE Oklahoma Platform Nemaha Uplift NE Flank Anadarko Basin	B/C	Campbell	Workshop completed 10/96
4. Peru Play (DesMoinesian)	Peru sd	NE Oklahoma Platform	C	Northcutt	Workshop completed 10/96
5. Prue & Skinner Plays (DesMoinesian)	Prue sd Skinner sd	NE Oklahoma Platform Nemaha Uplift NE Flank Anadarko Basin	A	Andrews	Workshops completed 6/96
6. Red Fork Play (DesMoinesian)	Red Fork sd	NE Oklahoma Platform Nemaha Uplift NW Anadarko Shelf NE Flank Anadarko Basin	A	Andrews	Workshops completed 3/97
7. Bartlesville Play (DesMoinesian)	Bartlesville sd	NE Oklahoma Platform Nemaha Uplift	A	Northcutt and Andrews	Workshops completed 10/97
8. Booch Play (DesMoinesian)	Booch sd	NE Oklahoma Platform	B	Northcutt	Workshop completed 9/95
9. Morrow Play (Morrowan)	Upper & Lower Morrow sd	NW Anadarko Shelf Hugoton Embayment	B	Andrews	Workshops completed 6/95

* "Class"is an estimate of the overall size of the play, based on geographic extent and on the number of reservoirs and operators in the play. Class "A"plays are the largest plays.

For each of the plays, a consistent format was developed for the presentation of materials. Presentations included both general materials regarding FDD depositional environments that were consistent for all of the plays, and specific materials that uniquely described the characteristics of each individual play.

For each workshop and folio publication, a series of tasks was completed. These tasks included data analysis and preparation of the publication by the authors; drafting of illustrations, figures, maps, and plates by the cartographic staff; editing; and publication. The workshop agenda was fairly standardized for all of the play presentations. Publicity for the workshops was through press releases and by mailouts to play operators as well as to all other operators and others who had attended past OGS workshops. For each workshop, announcement mailouts were to about 6,000 individuals and companies. Materials prepared for the workshops include 35mm slides, overhead transparencies, cores, field rock samples, and computer-generated production information maps. Each attendee at each workshop received a copy of the publication, and play operators who did not attend the workshops were given an opportunity to receive a complementary copy of the play publication.

Workshop sites for the various plays were identified based on areas of the greatest expected interest level. Lists of operators with recent production from the FDD plays were generated from the *NRIS* database. On the basis of operator addresses along with the number of operators in each FDD reservoir, potential sites were identified for each workshop presentation. Thus, for example, the Layton, Cleveland and Peru workshops were held in the Oklahoma City while the Prue and Skinner workshops were held in both Oklahoma City and Bartlesville.

The following paragraphs contain brief summaries of the play analyses and workshops completed for this program, in the order in which the workshops were completed.

THE MORROW PLAY

Primary author:	Richard Andrews
Workshop dates:	June 1 and 2, 1995
Workshop site:	Sarkeys Energy Center, Norman, OK.
Publication:	Oklahoma Geological Survey SP 95-1, Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Morrow Play.

Pennsylvanian Morrow sandstones are some of the most important oil and gas reservoirs in Oklahoma. Morrow sediments are Lower Pennsylvanian in age and consist of sandstone, shale, and limy clastics. The name is primarily a subsurface term that is used by the oil and gas industry in northwestern Oklahoma. The term Morrow is applied to the section of rock that extends from the base of the Atokan Thirteen Finger lime to the top of the Mississippian Chester limestone. This interval is highly variable, usually about 200-400ft thick throughout much of the Anadarko shelf, and thickens to over 4000ft in the basin depositional center in western Oklahoma. Wireline log responses change suddenly and correlations can be very difficult even over short distances. Additionally, fluvial sandstones often are interbedded with marine sediments and limestone indicating an unstable geological setting involving the interaction of several depositional environments in close proximity to one another.

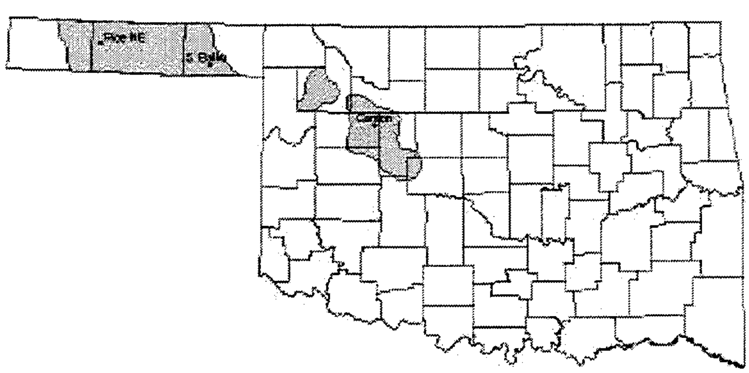

Figure 1 Generalized location map showing Morrow FDD areas.

Morrow fluvial systems are found principally in three regions within Oklahoma. The first area is the Dewey-Blaine Counties embayment. A second area in central Woodward County is located within a north-south trending paleo-valley and is commonly referred to as the Woodward "trench". The most extensive area of fluvial domination stretches across the Panhandle region comprising of

Texas, western Beaver, and eastern Cimarron Counties (Fig. 1). Distribution of fluvial or FDD sediments is directly related to the type of hydrocarbon produced from the Morrow. Morrow oil production occurs almost entirely in areas identified as FDD. One reason for this occurence is that sediments of fluvial origin are typically coarser grained and have better porosity than the relatively tight marine sands that mainly produce gas.

Detailed information was provided for three Morrow field studies: the Canton field area in Dewey County, the South Balko field in Beaver County, and the Northeast Rice field in Texas County. A reservoir characterization and waterflood simulation study was completed and presented for the Northeast Rice field.

Canton Field: The Canton study area consists of four sections that were originally part of Canton Southwest field before their assignment to the Watonga-Chickasha trend. Selection of the site was based upon oil production characteristics of the Morrow that are unique to the geologic province in which it occurs. It also has favorable well spacing (40 acres) and available current data such as cores, modern well logs, and production information. Table 2 gives a summary of geological/engineering data for the Canton study area.

TABLE 2 - Geological/Engineering Data for the Lower Morrow Sandstones in the Canton Study Area, Dewey County, Oklahoma

	lower Morrow "B" sand	*lower Morrow "C" sand*
Reservoir size	1,503 acres	1,960 acres
Well spacing (oil)	40 acres	40 acres
Oil/water contact	none	none
Gas /oil contact	none	none
Porosity	5-20% (10% avg)	5-20% (10% avg)
Permeability	1-200 md (1-10 avg)*	1-200 md (2-10 avg)*
Water saturation	20-45%	20-45%
Thickness (net sand in field)	10-20 ft (10.2 ft avg)	10-30 ft (12 ft avg)
Reservoir temperature	160-1700 F	160-1700 F
Oil gravity	40-470 API	40-470 API
Initial reservoir pressure	4,200 PSI**	4,200 PSI**
Initial formation-volume factor	1.2 reservoir barrels/stock tank barrels**	
Original Oil in Place (volumetric)	6,442 MSTBO	9,884 MSTBO
Cumulative primary oil	2,360 MSTBO (combined)	
Recovery efficiency (oil)	14.5% (combined)	
Cumulative gas	12.4 BCF (combined since 1979)	

*Source: South (1983). 'Source: Colton (1974a).

The Canton study area constitutes one of the most complicated assemblages of sediments in the entire Morrow FDD play. Numerous sand zones occur in a stratigraphic interval of only a few hundred feet and their thickness and lateral continuity is highly variable. Depositional origin apparently is very complicated since facies representative of marine, semimarine, and subaerial environments are in close proximity both vertically and laterally. The principal Morrow sandstones beds identified in the Canton area informally are called, in descending order, the "B", "C", and "D" sands. The structure of the Canton area is characteristic of a stable shelf or shelf-transition environment. Structure contours indicate basinward dip to the southwest at ~100 ft per mile which is equivalent to a 1° dip. There are no known faults or structural closures in the four-section study area.

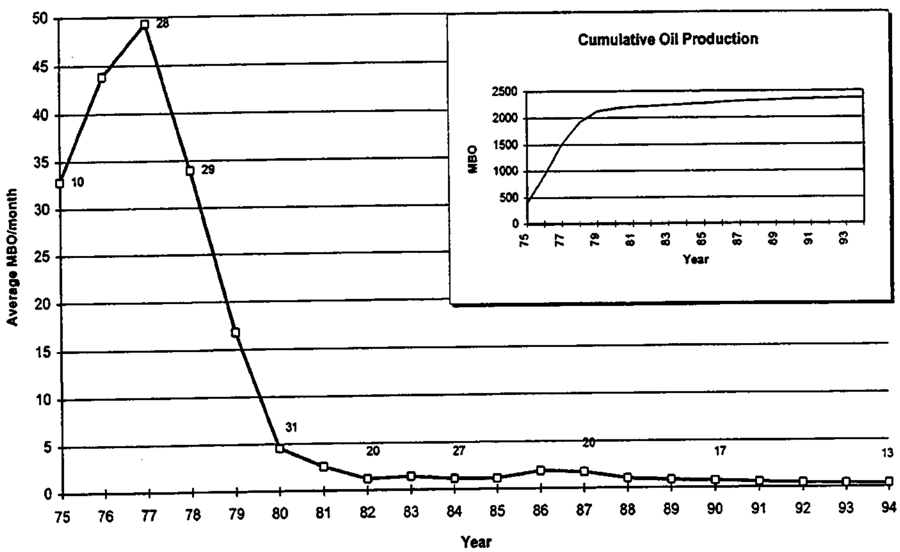

Figure 2. Oil-production decline curve for lower Morrow sandstones in the Canton study area. Numbers on the curve designate the number of wells that had Morrow production at various years. Inset plot shows cumulative production from the "B" and "C" sands combined.

Field development in the Canton area took place in the late 1970's and early 1980' s. There was a success rate of 92% for the 39 wells drilled: 35 produced from the Morrow, three were dry, and one produced from a deeper horizon. Almost all completions in the Morrow are classified as oil wells since they generally have a gas/oil ratio of <5,000:1. Cumulative primary oil production from all lower Morrow sandstones in the four section study area is estimated at 2,360 MSTBO, which is 14.5% of the estimated 16,326 MSTBO in place originally. The initially rapid recovery rate of oil followed by a quick decline in production is attributable to a strong solution-gas-drive mechanism within the reservoir. Once this energy was lost, oil production was reduced to very small quantities (Fig. 2).

South Balko Field: Production from the main part of the S. Balko field was established in December 1959, with the discovery of gas in the Oklahoma Natural Gas Co. No. 1 Custer well in sec. 9, T.1N., R.23ECM. The accredited discovery well was completed as a gas well in the western updip part of the field, now known as a gas cap. Production from this well is from the upper Morrow "A" sand at a depth of ~7,400ft. Initial calculated open-flow was estimated at 15MMCFGPD with a shut-in tubing pressure of 1,667 PSI. Total cumulative production from the No. 1 Custer well is estimated at 1.7 BCFG.

There are three main sandstones intervals in the upper Morrow section of the S. Balko field. In descending stratigraphic order they are called informally the "A", upper "B", and lower "B" sands. The upper Morrow "A" sand is the most continuous and uniformly deposited sandstone in the S. Balko area. It is present in two general areas in the study area and usually occurs as a single bed with a gross thickness of 20-40ft. The "A" sand is best developed within a meandering thalweg that is oriented in a northwest-southwest direction. The upper "B" is composed of several individual sandstone beds that occupy a stratigraphic interval of about 80-120ft. Predominant sandstones appear to be fluvial channel fill in nature, lenticular in aerial extent, and have scoured basal contacts. Only the lower sandstone in the upper "B" interval is productive. This zone seems to be the direct result of fluvial channel deposition. The lower "B" sand contains the most extensive distribution of sandstone in the S. Balko field and is commonly >40ft thick. However, this thickness includes many intervals that are shaley and that do not show significant GR or SP log responses. The lower "B" is only productive in a few wells in extreme northern parts of S. Balko field, and is not considered to be a significant reservoir.

Cumulative oil production through 1994 from the upper Morrow sands in S. Balko field is estimated at 4.8 million barrels. S. Balko field was unitized in 1972, but its not known whether it was successfully water flooded. A sharp decrease in the slope of oil production (Fig. 3) occurred during this time, and the number of producing wells dropped from 30 to 22. Since mid-1985, average production for individual wells has been <3 BOPD.

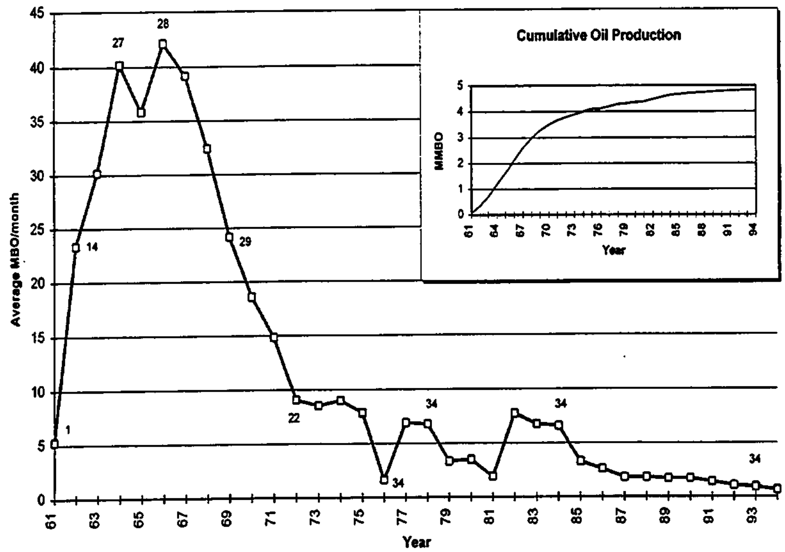

Figure 3. Oil-production decline curve for upper Morrow sandstones in S. Balko field. Numbers on the curve designate the number of wells that had Morrow oil production at various years. Inset plot shows cumulative oil from the "A" and "B" sands combined.

Rice Northeast Field is located along the east flank of Keyes dome which is part of the north-south trending Cimarron uplift that crosses the Oklahoma Panhandle. It was discovered by Apache Corp. in 1963 with the completion of the Gaither No. 1 well in sec. 23, T.3N., R.10ECM. That well was perforated from 5,192-5,220 ft and had an initial potential flowing of 140 Bbls of 36 gravity oil per day. Cumulative production from this well is estimated at 82MBO, which is generally better than average for this field.

The Morrow is subdivided into two intervals that are called informally the upper and lower Morrow. The lower Morrow is entirely marine in origin and consists mostly of shale. The upper Morrow contains multiple sands of both marine and nonmarine origin, but there are only two main sandstones which produce hydrocarbons, identified informally as the upper Purdy "B" and the lower Purdy "C" sands. Cumulative primary oil production through 1994 from the Purdy sands (combined) in Rice NE is estimated at ~1 million barrels (Table 3). An estimated 66% of the total primary oil recovery in Rice NE is attributed to the lower Purdy "C"sand. This zone had relatively stable oil production from only a few wells until the early 1980's, when Rice NE field expanded due largely to lower Purdy "C"completions in the southern part of the field.

Both of the Purdy reservoir sandstones are interpreted to have fluvial origins in a transgressive valley-fill depositional setting. They are separated from one another stratigraphically by about 10 to 40 ft of shale. Rice NE is bounded by major fault blocks on the east and west sides of the field. The updip fault in the west part of the field is interpreted to be the principal trapping mechanism for the upper Purdy "B"sand. The trapping mechanism for the lower Purdy "C"is predominantly stratigraphic.

TABLE 3. - Oil Production Statistics for Upper Morrow Purdy Sands (Combined) in Rice NE Field, Western Texas County, Oklahoma

Year	Number of Oil Wells* (estimated)	Annual Oil Production (Barrels)	Average Monthly Oil Production (Barrels)	Average Daily Oil Production Per Well (BOPD)	Cumulative Oil Production (Barrels)
63	4	28,750	2,396	19.7	28,750
64	5	40,896	3,408	22.4	69,646
65	4	35,721	2,977	24.5	105,367
66	4	40,458	3,372	27.7	145,825
67	4	33,617	2,801	23.0	179,442
68	4	27,873	2,323	19.1	207,315
69	4	25,411	2,118	17.4	232,726
70	6	26,029	2,169	11.9	258,755
71	5	25,622	2,135	14.0	284,377
72	5	24,294	2,025	13.3	308,671
73	4	21,052	1,754	14.4	329,723
74	4	20,825	1,735	14.3	350,548
75	5	18,076	1,506	9.9	368,624
76	5	16,288	1,357	8.9	384,912
77	5	13,100	1,092	7.2	398,012
78	6	15,465	1,289	7.1	413,477
79	6	12,506	1,042	5.7	425,983
80	6	10,081	840	4.6	436,064
81	5	8,655	721	4.7	444,719
82	8	26,403	2,200	9.0	471,122
83	12	94,978	7,915	21.7	566,100
84	14	138,648	11,554	27.1	704,748
85	12	83,199	6,933	19.0	787,947
86	12	68,463	5,705	15.6	856,410
87	13	46,971	3,914	9.9	903,381
88	13	32,085	2,674	6.8	935,466
89	11	25,002	2,084	6.2	960,468
90	12	20,452	1,704	4.7	980,920
91	12	17,598	1,467	4.0	998,518
92	11	16,206	1,351	4.0	1,014,724
93	10	9,938	828	2.7	1,024,662
94	10	7,525	627	2.1	1,032,187

*Based on number of producing leases. Individual leases may contain more than one producing unit.

THE BOOCH PLAY

Primary author: Robert Northcutt
Contributing authors: Kurt Rottmann, Roy Knapp, X. H. Yang
Workshop date: September 11, 1995
Workshop site: Indian Capital Vo-Tech School, Muskogee, OK
Publication: Oklahoma Geological Survey SP 95-3, Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Booch Play.

The Pennsylvanian sandstones in the Booch were significant oil reservoirs during the early history of the oil industry in Oklahoma. The Booch sands are the informal subsurface equivalents of the sandstone members of the McAlester Formation in the Krebs Group of the Desmoinesian Series. Booch reservoirs are still important today for potential recovery of additional oil by water-flooding or other enhanced recovery methods. Booch reservoirs dominantly occur in stratigraphic traps in fluvial-dominated deltaic environments, such as fluvial, upper and lower delta plain and delta-front deposits. Local uplifting and faulting, as well as sediment compaction, have influenced the localization of oil and gas in these traps.

The Booch play is located on the Cherokee Platform in northeastern Oklahoma and extends southward beyond the hinge line of the McAlester Formation into the Arkoma basin. The play area in Oklahoma is limited on the east and south by the outcrop of the McAlester Formation and on the west by depositional limit of sandstone in the Booch. The depth of the Booch sand increases from the surface outcrop in the east to 3,200 feet at the western limit of the play. A regional distribution map of the Booch sand in the play area is shown in Fig 4.

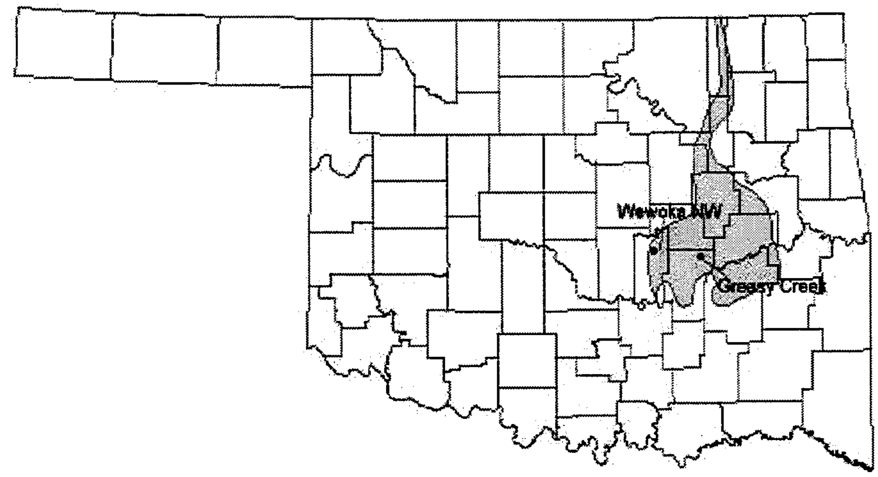

Figure 4. Generalized location map showing Booch FDD area.

Booch sediments are Middle Pennsylvanian in age and consist of shale, sandstone, and coal. Shales were deposited in marine, delta-front, lagoonal, and coastal-plain environments. Sandstones were deposited in distributary channels on the delta plain. Coals were deposited in the lagoonal areas associated with the delta plain. The top of the Booch is now recognized at the base of the overlying Savanna Formation or Brown Lime. The base of the Booch is at the top of the Hartshorne Formation, represented by the upper Hartshorne sand of the subsurface. This study of FDD reservoirs that produce the majority of the Booch oil includes only the play area on the Cherokee Platform, which produces both oil and gas.

Detailed information was provided for two Booch field studies: the Northwest Wewoka field area in Seminole County, and the Greasy Creek field in Hughes County. Additionally, a reservoir characterization and waterflood simulation study was completed and presented for the Greasy Creek field.

<u>Wewoka Northwest Booch Sand Unit</u> was originally part of the Cheyarha field and eventually was incorporated into the Seminole field in 1948. In 1989, Beard Oil Company unitized portions of secs. 4,5,7, and 8 of T.9N., R.7E. and portions of secs. 32 and 33 of T.10N., R.7E., and named it the Wewoka N.W. Booch Sand Unit. Production from the area of this unit had been established in 1944, with the discovery of oil from the Troup-Moore-Hall No. 1 Austin in sec 33, T.10N., R.7E. The discovery well was completed with an initial potential flow of 170 BOPD. Within two years, 55 additional oil wells had been completed and the field was fully developed (see Table 4). Cumulative oil production through 1994 was 2,539,922 BO for the Wewoka N.W. Booch unit. Secondary recovery in this field has yielded 4,710 BO through December 1991.

TABLE 4. - Oil Production Statistics for the Wewoka N.W. Booch Sand Unit, Seminole County, Oklahoma

Year	Number of Oil Wells	Annual Oil Production (barrels)	Average Monthly Oil Production (barrels)	Average Daily Oil Productio n (BOPD)	Cumulative Oil Production (barrels)	Year	Number of Oil Wells	Annual Oil Production (barrels)	Average Monthly Oil Production (barrels)	Average Daily Oil Productio n (BOPD)	Cumulative Oil Production (barrels)
1944	2	11,366	3,789	63	11,366	1970	23	10,478	873	1	2,445,365
1945	31	305,739	25,478	27	317,105	1971	23	12,540	1045	2	2,457,905
1946	54	728,361	60,697	37	1,045,466	1972	23	10,612	884	1	2,468,517
1947	56	559,021	46,585	28	1,604,487	1973	23	9,935	828	1	2,478,452
1948	56	126,315	10,526	6	1,730,802	1974	23	7,408	617	1	2,485,860
1949	56	145,843	12,154	7	1,876,645	1975	22	7,484	624	1	2,493,344
1950	53	113,600	9,467	6	1,990,245	1976	21	5,257	438	1	2,498,601
1951	52	68,335	5,695	4	2,058,580	1977	15	4,237	353	1	2,502,838
1952	52	51,787	4,316	3	2,110,367	1978	15	4,647	387	1	2,507,485
1953	52	45,032	3,753	2	2,155,399	1979	18	3,128	261	0	2,510,613
1954	52	41,553	3,463	2	2,196,952	1980	18	2,564	214	0	2,513,177
1955	48	30,460	2,538	2	2,227,412	1981	18	1,545	129	0	2,514,722
1956	48	23,537	1,961	1	2,250,949	1982	18	545	45	0	2,515,267
1957	48	19,390	1,616	1	2,270,339	1983	18	528	44	0	2,515,795
1958	46	18,669	1,556	1	2,289,008	1984	3	152	13	0	2,515,947
1959	33	14,553	1,213	1	2,303,561	1985	0	0	0	0	2,515,947
1960	31	13,952	1,163	1	2,317,513	1986	0	0	0	0	2,515,947
1961	29	14,398	1,200	1	2,331,911	1987	0	0	0	0	2,515,947
1962	29	13,468	1,122	1	2,345,379	1988	0	0	0	0	2,515,947
1963	27	12,319	1,027	1	2,357,698	1989*	8-4**	0	0	0	2,515,947
1964	27	12,567	1,047	1	2,370,265	1990	17-7**	2,712	226	0.4	2,518,659
1965	26	13,201	1,100	1	2,383,466	1991	3-7**	1,998	167	2	2,520,657
1966	26	14,187	1,182	2	2,397,653	1992	4-4**	14,969	1247	10	2,535,626
1967	23	12,854	1,071	2	2,410,507	1993	1-2**	3,240	270	9	2,538,866
1968	23	12,815	1,068	2	2,423,322	1994		1,056	88	0	2,539,922
1969	23	11,565	964	1	2,434,887	1995			0	0	2,539,922

*Wewoka N.W. area unitized into N.W. Wewoka Booch Sand Unit.
** Denotes number of injectors.
NOTE: The average daily oil production per well was calculated by dividing the average monthly production by 30 days and the number of active wells.

Greasy Creek Field, located in north-central Hughes County, Oklahoma, was discovered in 1945. Production is primarily gas from Pennsylvanian sandstones, although there are isolated instances of oil production in this large field. One of these reservoirs is the Booch oil reservoir discovered in the No. 1 Hall (sec. 4, T. 8 N., R. 11 E.), drilled by Bell Oil and Gas Company and completed in 1961. The well had an initial pumping potential of 36 BO and 96 BSWPD from perforations at 2,314-2,316 ft in the thick Booch channel sandstone. The reservoir was not fully developed until 1971, and it is still producing marginal amounts of oil.

The Booch oil reservoir is in a stratigraphic trap formed in sandstones deposited in a distributary channel that is incised into the prodelta marine shales of the lower Booch. The surrounding marine shales provide a logical source for the hydrocarbons in this reservoir although oil also may have migrated updip into the reservoir from the Arkoma basin before faulting sealed the reservoir. Oil production statistics for the Greasy Creek Booch oil reservoir through December 31, 1994, are shown in Table 5. Cumulative oil production from the reservoir was 692,315 BO. The reservoir only produced 4,120 Bo in 1994, an average of

6BOPD for the remaining two wells. The production peak in 1971 was the result of completion of 10 new oil wells.

TABLE 5. - Oil Production Statistics, Booch Oil Reservoir, Greasy Creek Field, Hughes County, Oklahoma

Year	Number of producing wells	Annual oil production (barrels)	Average monthly production (barrels)	Average daily production (barrels)	Average daily production per well (barrels)	Cumulative production (barrels)
1961	3	4,873	1,218	41	14	4,873
1962	4	21,212	1,768	59	15	26,085
1963	4	34,864	2,905	97	24	60,949
1964	4	41,195	3,433	114	29	102,144
1965	4	28,342	2,362	79	20	130,486
1966	4	26,520	2,210	74	18	157,006
1967	5	39,286	3,274	109	22	196,292
1968	5	45,657	3,805	127	25	241,949
1969	5	30,018	2,502	83	17	271,967
1970	10	77,064	6,422	214	21	349,031
1971	13	102,065	8,505	284	22	451,096
1972	11	49,576	4,131	138	13	500,672
1973	11	27,824	2,319	77	7	528,496
1974	10	20,647	1,721	57	6	549,143
1975	10	13,959	1,163	39	4	563,102
1976	8	11,416	951	32	4	574,518
1977	7	13,866	1,156	39	6	588,384
1978	7	10,006	834	28	4	598,390
1979	7	11,090	924	31	4	609,480
1980	5	11,376	948	32	6	620,856
1981	5	9,720	810	27	5	630,576
1982	5	10,308	859	29	6	640,884
1983	5	7,668	639	21	4	648,552
1984	5	6,709	559	19	4	655,261
1985	5	5,621	468	16	3	660,882
1986	5	3,378	282	9	2	664,260
1987	5	3,058	255	8	2	667,318
1988	5	2,661	222	7	1	669,979
1989	5	3,704	309	10	2	673,683
1990	5	3,466	289	10	2	677,149
1991	5	3,261	272	9	2	680,410
1992	5	3,896	325	11	2	684,306
1993	4	3,889	324	11	3	688,195
1994	2	4,120	343	11	6	692,315

Sources: Petroleum Information Corporation, Oklahoma Crude Report, and Natural Resources Information System (NRIS).

THE LAYTON AND OSAGE-LAYTON PLAYS

Primary author: Jock Campbell
Contributing authors: Dennis Shannon, Victoria French, Roy Knapp, X. H. Yang
Workshop date: April 17, 1996
Workshop site: Francis Tuttle Vo-Tech Center, Oklahoma City, OK
Publication: Oklahoma Geological Survey SP 96-1, Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Layton and Osage-Layton Play.

The Layton and Osage-Layton sands are informal names that have become part of the subsurface geologic nomenclature in northeastern Oklahoma. Layton is a driller's name that dates to the early part of this century. The name Osage-Layton originated from an attempt to correct a recognized misidentification of a younger sandstone interval as Layton. The Layton and Osage-Layton sand occur in the Missourian Series of Pennsylvanian System but have never been defined by the geological community, and the applications of those names continue to vary locally according to individual discretion.

The Layton sand is now well understood to occur high in the shale, sandstone, and carbonate sequence above the Checkerboard Limestone and below the Hogshooter Limestone. These strata belong to the Coffeyville Formation or the Coffeyville Subgroup. The Layton sand is most commonly described as a fine- to very-fine-grained sandstone with common associations of mica and clay minerals. The Osage-Layton sand is now correctly identified as the Cottage Grove Sandstone, a member of the Chanute Formation. In common industry usage, Osage-Layton designates the "eastern" facies of the Cottage Grove Sandstone, which is largely of flood-plain and deltaic in origin. The name Cottage Grove most commonly is used in association with the "western" facies, which is of marine origin. The Osage-Layton is commonly described as a fine- to very fine-grained sandstone. It is commonly silty and micaceous, indicating low-energy environments of deposition. The Cottage Grove/Osage-Layton sand is commonly thicker and exhibits a much greater area of distribution than the Layton sand.

The FDD Osage-Layton and Layton plays occur in a relatively small area in northeastern Oklahoma (Fig. 5). Within this area, hydrocarbon production from the Layton sands is attributed to several horizons within a stratigraphic interval of several hundred feet. Although historical production records are not available, the Layton sands in the FDD study area are generally prone to oil rather than gas production. During the last 17 years, the Layton sands have produced about 11,467,000 barrels of oil.

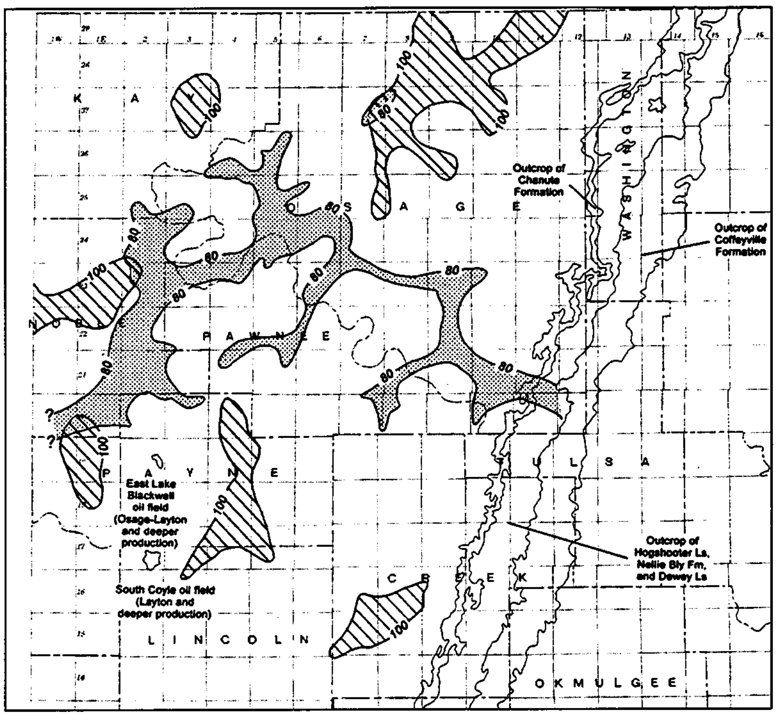

Figure 5. Maximum net thickness of Layton and Osage-Layton sandstones in the deltas area. Layton sand (stippled); minimum thickness shown is 80 ft (after Ekebafe, 1973). Osage-Layton sand (hachured); minimum thickness shown is 100 ft (after Lalla, 1975a). Outcrop areas from Miser (1954).

Two detailed geologic field studies were prepared for this workshop. South Coyle field is a Layton sand reservoir that lies stratigraphically below the Osage-Layton interval; this study was completed by consulting geologist Dennis Shannon. East Lake Blackwell field is an Osage-Layton sand reservoir and the geological study for this field was completed by Jock Campbell and Victoria French. The geologic interpretation of East Lake Blackwell also was used in the waterflood simulation study by Roy Knapp and X. H. Yang.

South Coyle Field is located in T. 17N R. 1E in Logan and Payne Counties, Oklahoma. The Layton sand is defined stratigraphically as sandstones in the interval between the Hogshooter Limestone and the Checkerboard Limestone. Layton production in the field area originally was established in 1947, with the discovery of oil in Layton sand in the Gulf Oil Corporation No. 1 Bliss well, sec. 26, T. 17N, R. 1E from perforations at 3,634-3,658 ft. This well was completed for an initial potential pumping of 11BOPD + 125bbl of water per day with an oil gravity of 47.6° API. This first producing well was abandoned at an unknown date after producing only 2,042 BO. The next Layton completion didn't occur until 34 years later, when the Funk Exploration, Inc., No. 1 Woods well in section 28 produced from perforations at 3,704-3,730 ft. The Layton was completed in that well in June 1981and had an IPF of 26 BO, 2 BW, and 150 MCFGPD.

Oil production occurs in an indistinctly defined shaley interval approximately 40-80 ft below the top of the Hogshooter Limestone. The producing sandstones in the Layton interval typically are very shaley. Resistivities are low, ranging from ~1 to 5 ohm-meters, due in large part to the shaliness of the sandstones. The South Coyle field occurs on a structural terrace, seen as a slight flattening of a homoclinal dip to the west at 75-150 ft/mi. Structural position seems to have played no part in the Layton accumulations.

Field development continued from November 1983 through August 1988. By June 1995 the Layton reservoir in the South Coyle field had a total of 14 wells, with a cumulative production of almost 190,000 BO. The cumulative production for the best single well was 35,756 BO over a ten year period. The average for the 14 field wells is slightly more than 13,500 bbl/well. Casinghead gas has been reported from only one well and is minor, with a cumulative production of 17,324 MCF over a 3.5 year period. This reservoir is difficult and economically risky as a primary exploration objective, however, it provides for understanding of the keys to production. The Layton sand will continue to be a secondary, and locally a primary zone of interest over a large geographic area.

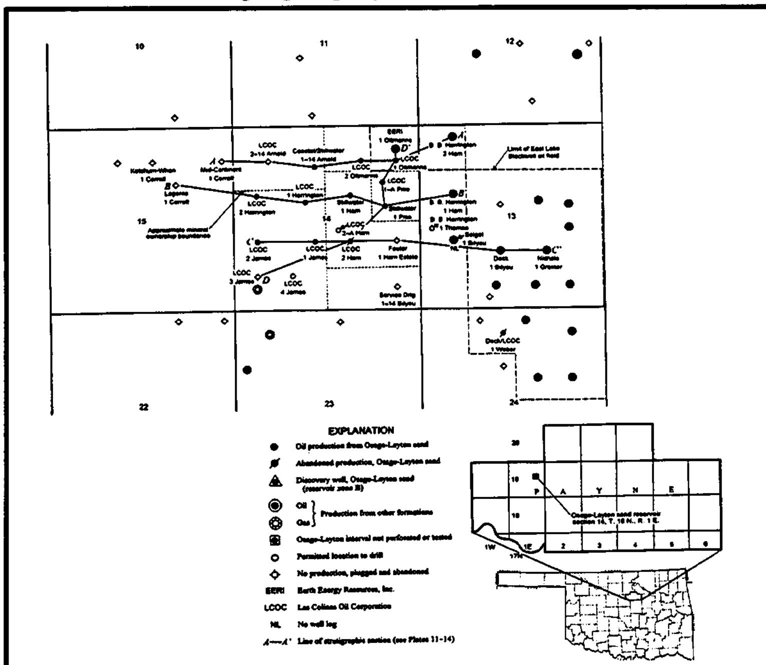

Figure 6. Information map of the East Lake Blackwell oil field area, sec. 14, T. 19N., R. 1E., northwestern Payne County, Oklahoma.

East Lake Blackwell Field is in north central Oklahoma in western Payne County (Fig. 6). It was discovered in 1987 as a recompletion of the Coastal #1 Arnold well in sec. 14, T. 19N., R. 1E., and had initial production of 22 BOPD. It was found that the Osage-Layton interval consisted of several producing sand zones. Mapped together, the sandstone comprising the stacked channel sequence has a gross thickness of about 20-100 feet, but in the field area the cumulative sandstone thickness is only about 35-40 feet thick. Thickening occurs down-dip to the west and thinning occurs up-dip to the east. The reservoir lies at a depth of about 3300 feet and hydrocarbon trapping results from a combination of structural nosing and an up-dip reduction in net sandstone and porosity.

Total cumulative primary oil production from East Lake Blackwell Field is estimated to be 320,000 BO which is about 12% of the original oil in place (2.6 MMBO). The field produces from four different zones and by the end of 1994, there were 10 producing oil wells completed in the Osage-Layton interval. Reservoir properties are very favorable for secondary water flooding since the sandstone generally has relatively high porosity (~15-18%) and permeability (~10-50 md). These data are summarized in Table 6.

TABLE 6 - Reservoir Properties, Osage-Layton Reservoir, East Lake Blackwell Field, Payne County, Oklahoma

Estimated properties	Zone A	Zone B	Zone C	Zone D
Porosity	12-22%	15.5%	17%	18%
Permeability	10-50 md	35md	40md	35md
Average Gross Pay	70 ft	50 ft	60 ft	20 ft
Average Net Pay	11 ft	6 ft	14 ft	8 ft
Initial Water Saturation	46%	46%	46%	46%
Initial Bottom-Hole Pressure	1,450 PSIA	1,440 PSIA	1,430 PSIA	1,430 PSIA
Initial Gas-Oil Ratio	400 SCF/STB	400 SCF/STB	400 SCF/STB	400 SCF/STB
Initial Formation-Volume Factor	1.22 RB/STB	1.22 RB/STB	1.22 RB/STB	1.22 RB/STB
Reservoir Temperature	110^{o} F	110^{o} F	110^{o} F	110^{o} F
Oil Gravity	43.0^{o} API	43.0^{o} API	43.0^{o} API	43.0^{o} API
Specific Gas Gravity	0.95	0.95	0.95	0.95
Initial Oil in Place	1.6 MMSTB	0.51 MMSTB	0.39 MMSTB	0.10 MMSTB

The summary of oil production is included in Table 7 which also indicates the secondary oil recovery expected for different development cases. Waterflood modeling by Knapp and Yang indicates that unproduced mobile oil amounts to about 1.4 MMSTBO or 52% or the OOIP. Various secondary recovery scenarios were examined and they indicate that the amount of additional recoverable oil varies from 32% to 233% of primary production (Table 7). The various scenarios include production from existing well completions in addition to cases involving recompletions and infill development drilling.

TABLE 7 - Oil Recovery Comparisons for Different Development Cases, Osage-Layton Reservoir, East Lake Blackwell Field, Payne County, Oklahoma

	Primary (9/30/1995)			Base (12/31/2005)			Recompletion (12/31/2005)			Infill Wells (12/31/2005)		
Formation	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (Barrels)	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (Barrels)	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (Barrels)	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (Barrels)
Zone A	227,000	14	850,000	310,000	19	1,800,000	500,000	31	1,500,000	570,000	36	1,800,000
Zone B	75,000	15	28,000	82,000	16	44,000	260,000	50	160,000	280,000	55	160,000
Zone C	6,000	1.5	240,000	7,000	1.8	470,000	165,000	42	690,000	186,000	48	580,000
Zone D	12,000	12	42,000	22,000	22	90,000	15,000	15	56,000	30,000	30	70,000
Total	320,000	12	1,200,000	421,000	16	2,400,000	940,000	36	2,400,000	1,066,000	41	2,600,000

THE SKINNER AND PRUE PLAYS

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Workshop sites:	Francis Tuttle Vo-Tech Center, Oklahoma City, and Phillips Petroleum Co. Research & Development Center, Bartlesville, OK.
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Similarities in depositional origin, stratigraphy, age, and environments of deposition made it convenient to group the Prue and Skinner plays into one workshop. Major topics included in the publication and workshop consisted of the regional analysis of each play along with three Skinner field studies and one Prue field study. Fields were selected because of their appropriate size (aerial extent and cumulative oil production), availability of core data and modern electric well logs, and availability of recent production information. The four fields have diverse geologic characteristics that typify many of the clastic reservoirs in the Cherokee Platform of eastern Oklahoma. Two of the fields have already been water flooded which provided a good analogy for this technology. Enhanced recovery simulation studies were completed on one Prue and one Skinner reservoir. Computer modeling utilized software demonstrated in previous workshops (Eclipse) in addition to Boast III which is more user-friendly and widely available to the public.

The Skinner Play

In terms of stratigraphic thickness and aerial distribution, the Skinner is probably the largest single play in the Oklahoma FDD series. During the past 17 years, estimated annual Skinner oil production has been between 1.2 and 3 MMBO. The actual production rate is probably considerably higher due to the fact that much of the Skinner oil production is commingled and not always distinguished separately. These data are summarized in Table 8.

TABLE 8. - Annual Oil Production from Oklahoma Skinner and Prue Reservoirs, 1979-95

	Skinner only		Skinner commingled with other reservoirs		Prue zones only		Prue commingled with other reservoirs	
Year	Production (MBO)	# of leases	Production (MBO)	# of leases	Production (MBO)	# of leases	Production (MBO)	# of leases
79	1,174	581	3,958	1,078	1,347	332	3,077	562
80	1,279	680	4,091	1,283	1,283	361	3,062	656
81	2,110	791	5,214	1,523	1,267	385	3,152	729
82	2,298	891	5,619	1,756	1,634	472	3,956	889
83	2,265	937	5,648	1,861	1,800	534	4,256	990
84	2,669	1,032	6,125	2,019	1,959	597	4,197	1,089
85	2,706	1,087	5,947	2,106	2,179	647	4,360	1,168
86	2,791	1,094	6,016	2,098	1,995	650	4,079	1,179
87	2,973	1,069	5,581	2,061	1,549	610	3,150	1,135
88	2,776	1,018	5,232	1,989	1,260	606	2,671	1,107
89	2,329	1,043	4,511	2,045	1,127	640	2,534	1,157
90	2,080	1,057	4,117	2,040	1,246	627	2,611	1,132
91	2,128	968	4,045	1,902	1,177	614	2,457	1,084
92	1,877	906	3,718	1,823	1,078	602	2,335	1,063
93	1,497	883	3,238	1,781	884	513	2,037	974
94	1,439	792	3,093	1,602	820	490	1,963	897
95	1,592	808	3,112	1,579	742	477	1,831	910
Total (MBO)	35,982		79,264		23,346		51,726	

NOTE: Production data from NRIS. MBO = thousand barrels of oil.

The Skinner interval is typically defined as the interval between the Verdigris limestone and the Pink lime. Skinner sands are middle Pennsylvanian in age and belong to the upper "Cherokee"Group. The Skinner interval is commonly 100-250 ft thick and is informally divided into an upper and lower zone, although in many areas a middle zone is also distinguishable. Skinner sands are generally very fine to fine grained, although medium- to coarse grained sand is sometimes observed. The sand consists mostly of quartz, averaging 66-80% depending on location. Porosity is primarily secondary and fracturing was not documented in most references used in this study.

Sandstones in the Skinner interval originated from major fluvial systems that advanced across much of the Cherokee platform in a southwest direction (Fig. 7). The Skinner sand was probably deposited in a transitional environment ranging from subaerial coastal plain and deltaic to shallow marine. The depositional slope throughout most areas in the Cherokee platform was very small, which inhibited thick accumulations of sediment particularly basinward. Therefore, some of the thickest Skinner sandstones occur in fluvial channels. Certain episodes of Skinner deposition were suppressed in central Oklahoma by positive elements along the Nemaha fault zone. A few major fluvial systems did advance into the western part of the Anadarko basin. These depositional phases occurred primarily during upper Skinner time and are mapped in western Oklahoma as far as Roger Mills County. Much of the Skinner sandstone occurs east of the Nemaha fault zone and lies stratigraphically in the lower or middle part of the Skinner section. In the southeastern part of Oklahoma, the Skinner merges with a much thicker depositional system in the Arkoma basin. In this area, the stratigraphic equivalent of the lower Skinner sand interval is referred to as the lower Senora Formation, Chelsea Sandstone, or Allen sand. In general, the Skinner FDD system was sourced by the Ouachita uplift and advanced to the northwest.

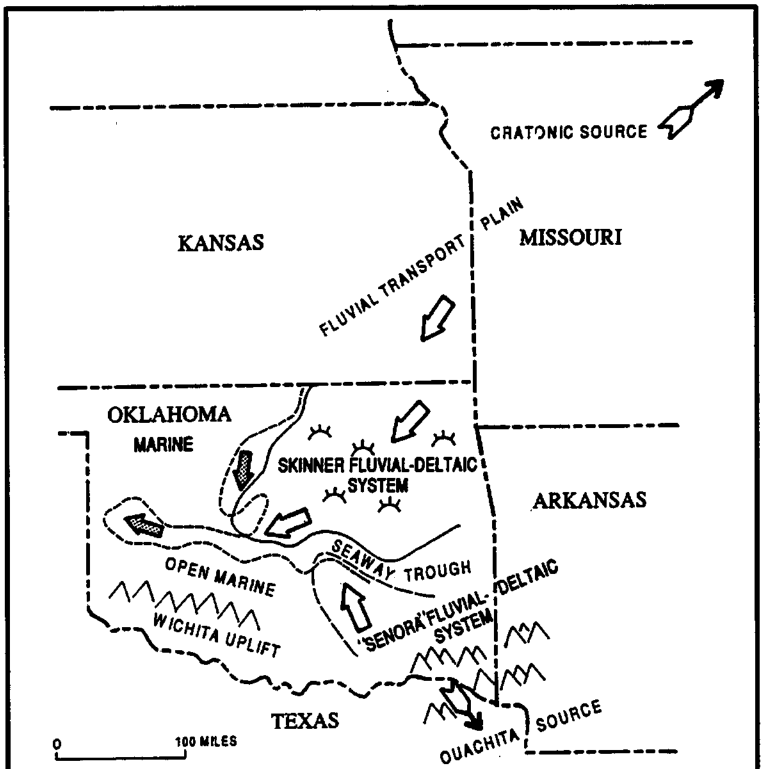

Figure 7. Paleogeography of the central Midcontinent region during deposition of Skinner and Senora (often called Allen or Chelsea) sandstones. Solid outline indicates areas of lower and middle Skinner sandstone and equivalents, whereas the dashed outline indicates the regional extent of the upper Skinner sandstone.

Production from the Skinner and Senora sands is highly gas prone, and becomes entirely gas in the deeper portions of the Anadarko and Arkoma basins. Most marine and fluvial reservoirs have good-to-excellent reservoir properties, with some problems from compartmentalization and highly variable permeability. In order to characterize these important reservoirs, three detailed geologic field studies were completed involving reservoirs of fluvial origin. Two of the Skinner fields have already undergone successful water flooding and are useful analogies to this commonly employed secondary recovery technique. These are the Perry SE field and Guthrie SW field, with basic reservoir and engineering data as shown in Table 9.

TABLE 9 - Reservoir Properties for the Perry S.E. and Guthrie S.W. Skinner Sand Units

	Perry S.E.	Guthrie S.W.
Reservoir size	610 acres	583 acres
Spacing (oil)	40 acres	40 acres
Oil/water contact	none	~-4625 feet
Gas/oil contact	none	none
Porosity (average)	15%	15%
Permeability (average)	15 md average	not determined
Water saturation (calculated)	36%	20%
Average Gas-Oil Ratio (GOR)		
Initial	492 SCF/BO	800 SCF/BO
Final	n.a.	4808 SCF/BO
Average Thickness	12.5 feet	6.8 feet
Reservoir Temperature	122° F	128° F
Oil Gravity	41° API	42° API
Initial reservoir pressure	~2000 PSI	~2367 PSI
Initial formation-volume factor	1.24 RB/STB	1.4 RB/STB
Original Oil in Place (volumetric)	4,591,000 STBO	2,467,000 STBO
Cumulative primary oil production	639,000 STBO	312,761 STBO
Cumulative primary oil recovery	84 BO/acre-ft	79 BO/acre-ft
Recovery efficiency (oil)	~13.9%	~12.6%
Cumulative primary gas production	Not determined	~1.5 BCF

Southeast Perry Skinner Sand Unit is located in Noble County in north-central Oklahoma in the southern part of the Perry Townsite field (Fig. 8). The Perry S.E. study area lies about 18 miles east of the Nemaha fault zone and in an area often referred to as the Cherokee platform province. The first well in the study area that produced oil from the Skinner was the MacKeller, Inc. No. 1 Warren well (sec. 25, T. 21N R. 1W). The well was completed in 1983, with an initial pumping potential of 45 BO, 175 MCFG, and 20 BLW per day. Within two years, 22 additional oil wells were completed in the lower Skinner. The log signatures of the thick Skinner sandstone generally display a sharp basal contact, blocky SP and gamma-ray profile through the body of the sandstone, and at the top, a fining- or shalier-upward gamma ray profile, which indicates that this is a channel sandstone in a fluvial depositional environment.

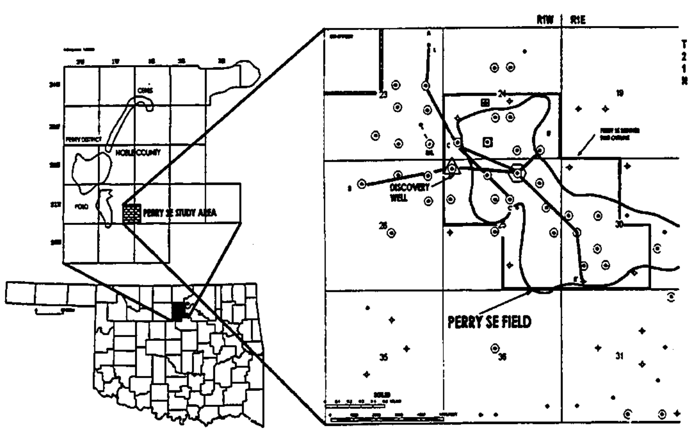

Figure 8. Generalized location map of Perry S.E. field study area, Noble County, Oklahoma. Solid black line is the outline of the Perry S.E. Skinner Sand Unit pool..

Primary oil production was 639,000 BO for the Perry S.E. Skinner Sand Unit, with an oil recovery factor prior to unitization of ~13.9%.. The field was unitized for secondary recovery on December 1, 1989. Water injection started on January

1, 1990, resulting in a production increase that has led to cumulative production of 1,318,268 BO through the first six months of 1995.

__Southwest Guthrie Field__ is located in southern Logan County in central Oklahoma (Fig. 9). Regionally, the field is located just east of the Nemaha fault zone in the region between the Cherokee platform to the east and the Anadarko basin and shelf provinces to the west. Most of the Guthrie S.W. production is from the lower Skinner sandstone. Commercial production was first established with the 1983 completion of the Harper Oil Co. No. 1 Davis well in sec. 36, T. 16N., R. 3 W. The initial potential flow reported was 38 BOPD and 442 MCFGD from the lower Skinner sand. The field was fully developed within three years by the completion of seven lower Skinner oil wells.

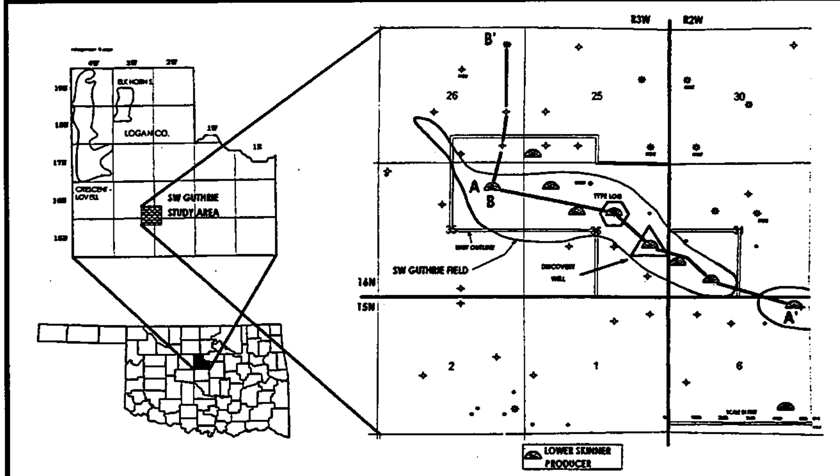

Figure 9. Generalized location map of the Guthrie S.W. field study area in southern Logan County, central Oklahoma.

The Pink limestone, which generally defines the base of the Skinner zone, is absent in the study area. So, the Skinner zone is the interval from the base of the Verdigris Limestone to the unconformity, which is at the top of the Woodford Shale. The log signature of the sandstone is very similar in all the wells in the cross section and suggests that this could be a channel facies of a fluvial depositional environment. The Skinner sand within the reservoir approaches 20 ft in thickness in the center of the channel. Table 10 shows oil production statistics for the unit.

TABLE 10. - Oil Production Statistics for the Guthrie S.W. Skinner Sand Unit, Logan County, Oklahoma

Year	Number of Oil Wells	Average Annual Oil Production (Barrels)	Average Monthly Oil Production (Barrels)	Average Daily Oil Production (BOPD)	Cumulative Oil Production (Barrels)
1983	1	19,781*	1,978	66	19,781
1984	3	89,283	7,440	83	109,064
1985	6	97,842	8,154	45	206,906
1986	7	39,542	3,295	16	246,448
1987	7	21,832	1,819	9	268,280
1988	7	15,782	1,315	6	284,062
1989	7	8,677	723	3	292,739
1990	7	8,594	716	3	301,333
1991	7	6,961	580	3	308,294
1992**	5	4,467	372	2	312,761
1993	5	3,741	312	2	316,502
1994	5	72,391	6,033	40	388,893
1995	5	65,949***	8,244	55	454,842

* 10 months of production
** unitized Feb. 1, 1992, 2 producers were converted to water injection wells
*** 8 months of production

Salt Fork North Field was discovered in 1981 and developed by DEM Operating - a small Oklahoma operator. The field is located in Grant county in north central Oklahoma (Fig. 10) and consists of 15 producing wells. The field was unitized for purposes of water flooding in

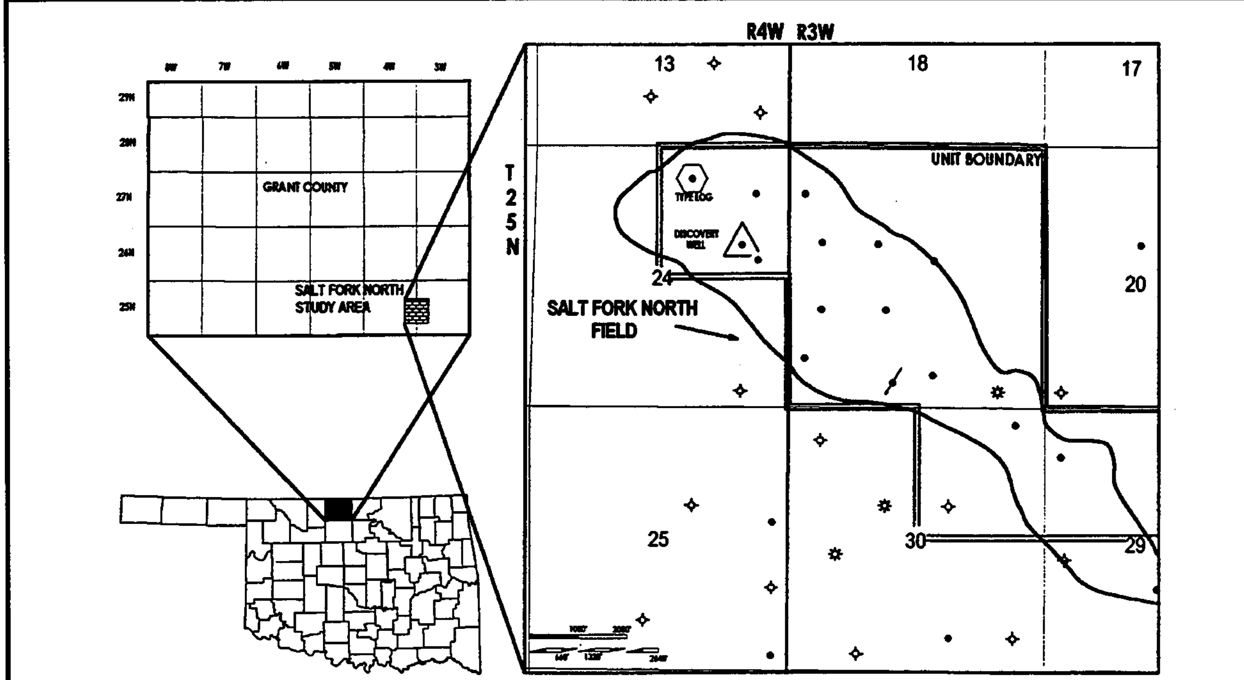

Figure 10. Generalized location map of the Salt Fork North study area in southeast Grant County, Oklahoma.

December 1994 and "experimental" water injection was attempted the following year. However, because of rapid breakthrough of the water in a nearby well, the waterflood was discontinued. Total primary production is estimated at 232 MBO and 1.6 BCF.

The Skinner reservoir consists of an upper and lower sand zone. The upper sand has a net thickness of about 10-20 feet and is productive throughout the field. Within the field boundary however, the upper sand occurs in two pods that might be compartmentalized (secs. 19 and 24, T. 25N., R. 3W). The upper Skinner sand also is productive in a field just to the south (sections 25 and 30) and is inferred within the western portion of section 29. The lower Skinner sand is generally thicker and has a net sand accumulation of about 10 to over 30 feet. It occurs in a narrow meandering band that is about 1/3 mile wide and at least two miles long. Hydrocarbon production from the lower Skinner is highly affected by the structural position of the sand and is best in the southeastern part of the field that is sufficiently above an inferred oil/water contact.

During the initial evaluation of this field, it became apparent that oil production was not very good considering the thickness of reservoir sand and the apparent good porosity. Then, reservoir data was acquired from cores for two wells just south of Salt Fork North that is believed to be representative of reservoir conditions within the field study. These data indicate that the Skinner reservoir is relatively tight since the average permeability is only about 4 md. With such low permeability, it is understandable why a large sand fracture was necessary to bring the wells on-line. The summary of geologic and engineering data for the Skinner sands in Salt Fork North field is shown in Table 11.

TABLE 11 - Reservoir Properties for the Salt Fork North Field Skinner Sandstones in Grant County, Oklahoma		
	Lower Skinner Sand	Upper Skinner Sand
Reservoir size	~375 acres	~645 acres
Spacing (oil)	40 acres	40 acres
Oil/water contact	~ -3950	above ~ -3950
Gas/oil contact	undetermined	undetermined
Porosity	10-18% (avg 12%)	10 - 19% (avg 13%)
Permeability[1]	0.25-8 md (avg 4 md)	0.25-8 md (avg 4 md)
Water saturation (calculated)	26-60% (avg 41%)	33-50% (avg 43%)
Thickness[2]	10-20 ft (avg 16 ft)	10-35 ft (avg 12 ft)
Reservoir Temperature	125° F	125° F
Oil Gravity	40-42° API	40-42° API
Initial reservoir pressure	1,826 PSI	1,826 PSI
Initial formation-volume factor	1.3 RB/STB	1.3 RB/STB
Original Oil in Place (volumetric)	2,376,000 STBO	3,137,000 STBO
Cumulative primary oil production	73,337 STBO (est)	159,313 STBO (est)
Recovery efficiency (oil)	3.1%	5.1%
Cumulative gas[3] production	336,044 MCF	1,286,000 MCF

1 Based on permeabilities measured in cores from two Skinner wells located a few miles south of the study area.
2 Entire sand bed thickness. In places, adjacent to the oil-water contact, the thickness of net sand above the oil-water contact is somewhat lower than the entire sand bed thickness.
3 Not including produced gas used for on-site power generation.

Primary oil production in Salt Fork North was essentially complete by early 1996 when modeling for this project was initiated. Because the low permeability of the Skinner reservoir meant that simple water flooding had a very long response time, alternative recovery techniques were modeled by Knapp and Bhatti. Immiscible gas injection and alternating gas/water injection (WAG) scenarios were tried which significantly reduced the oil production response time. The predicted outcome of exploitation schemes are compiled in Figure 11. Based upon this modeling effort, it was learned that in a relatively tight sand reservoir, an alternating gas/water injection program (WAG) was optimal (without regard to economics). In this study, using the WAG model, recovery of more than 500 MSTBO (15% OOIP) was predicted over a 15 year period, which is over 2.1 times the primary recovery. This assumed injection of 4.2 MMMCFG and 2.2 MMSTBW. The simulation projected that most of the injected fluids and gas were ultimately recovered by the end of the 15 year enhanced recovery period.

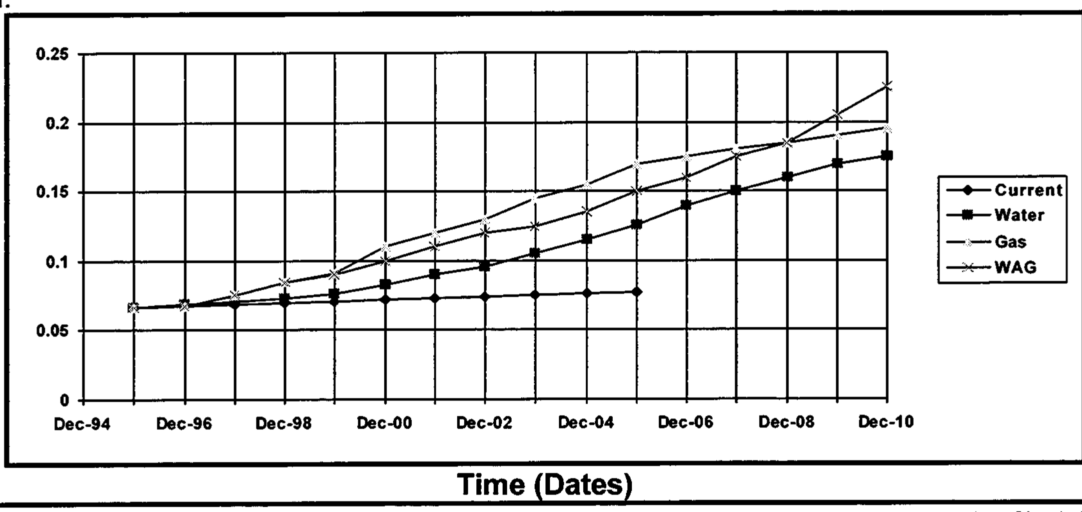

Figure 11: Predicted outcome of exploitation schemes from 1996 to 2010: % Recovery of Original Oil in Place based on Simulation Results

The Prue Play

The upper "Cherokee" Prue sand was first referenced in 1921, by White and Green from its occurrence in the Prue Field in Osage County, Oklahoma. During the early 1900's, Prue oil production was quickly exploited in northeastern Oklahoma, particularly in structural closures where it was often the shallowest productive "Cherokee" reservoir. The Prue sandstone is confined to the Cherokee platform and shallow shelf area of the Anadarko basin. In the northern part of this area, Prue sandstones are primarily fluvial; however they become increasingly more marine southward. Sandstones in this section are usually about 10-50 ft thick and fine to very fine grained.

Prue oil production is commonly commingled with production from other reservoirs, making statistical compilations of production misleading. Overall, Prue oil production is characterized by moderate annual fluctuations and has ranged from about 0.75-2 MMBO over the past 10 years, with a moderate decline since 1987. Since the mid-1980's annual Prue oil production was consistently about 0.75-1.0 MMBO less than that from the Skinner. These data were summarized in Table 8.

The Prue is a very commonly-used subsurface term that refers to a sand interval consisting of usually one or two individual sand zones. When more than one distinct sand zone is present, they are not always separated by a distinctive marker bed such as coal, limestone, and/or hot shale beds as are the Skinner zones. At outcrop, the formal equivalent name of the Prue sand is the Lagonda Sandstone, although this terminology is seldom used by the oil industry. Because of correlation problems in southeastern Oklahoma, the Prue sands are commonly referred to as the Calvin Sandstone - a formal surface name.

The Prue play is located primarily in the eastern half of the state in the Cherokee Platform Province. Progradation of the Prue FDD system to the southwest took place in a manner similar to the Skinner but deposition was not as extensive or intensive. As a result, Prue deposition was redirected southward away from structurally positive areas arising along the Nemaha Uplift, thereby inhibiting the transport of coarser grained sediments into the Anadarko basin. The stagnation of the Prue FDD system resulted in very dirty reservoirs containing abnormally high amounts of clay and mica. Subsurface evidence marking the maximum westward extent of Prue FDD occurs along the southern extent of the Nemaha fault zone just west of Oklahoma City. The southern limit of the Prue FDD system adjoins a marine seaway. In approximately the same stratigraphic position, a similar depositional sequence originated in far southeastern Oklahoma (Arkoma Basin) and prograded to the northwest. The Prue "equivalents" in this part of the state are referred to as the Calvin sands, and are much thicker than the Prue interval of the Cherokee Platform Province farther to the north.

Hydrocarbon production from the Prue and Calvin sands is highly oil prone although a significant proportion of well completions are classified as gas wells. Since this play does not extend into the deeper part of the Anadarko basin, there are no large areas of production that are entirely gas. Most of the reservoirs, whether marine or fluvial, are second-rate and do not produce as well as the cleaner reservoirs found in the Bartlesville, Red Fork, and some Skinner zones. Another problem with Prue reservoirs is formation evaluation because the sands often calculate wet. This is due to errors in the interpretation of true (deep) resistivity which is suppressed by the high interstitial clay content. Clean sands in the Prue interval are sometimes difficult to interpret from gamma-ray logs because of the unusually high mica content in the reservoir. Other drawbacks that are inherent to this class of reservoirs include compartmentalization and highly variable permeability. These problems were addressed in the evaluation of the Prue oil pool in Long Branch field.

Long Branch Field, Prue oil pool is located in Payne county in north central Oklahoma (Fig. 12). The field is in the western part of the Cherokee platform province and is ~45 mi east of the Nemaha fault zone. Prue production was discovered and commercially produced early in 1993 despite several earlier Prue penetrations in the center of the field. These earlier wells

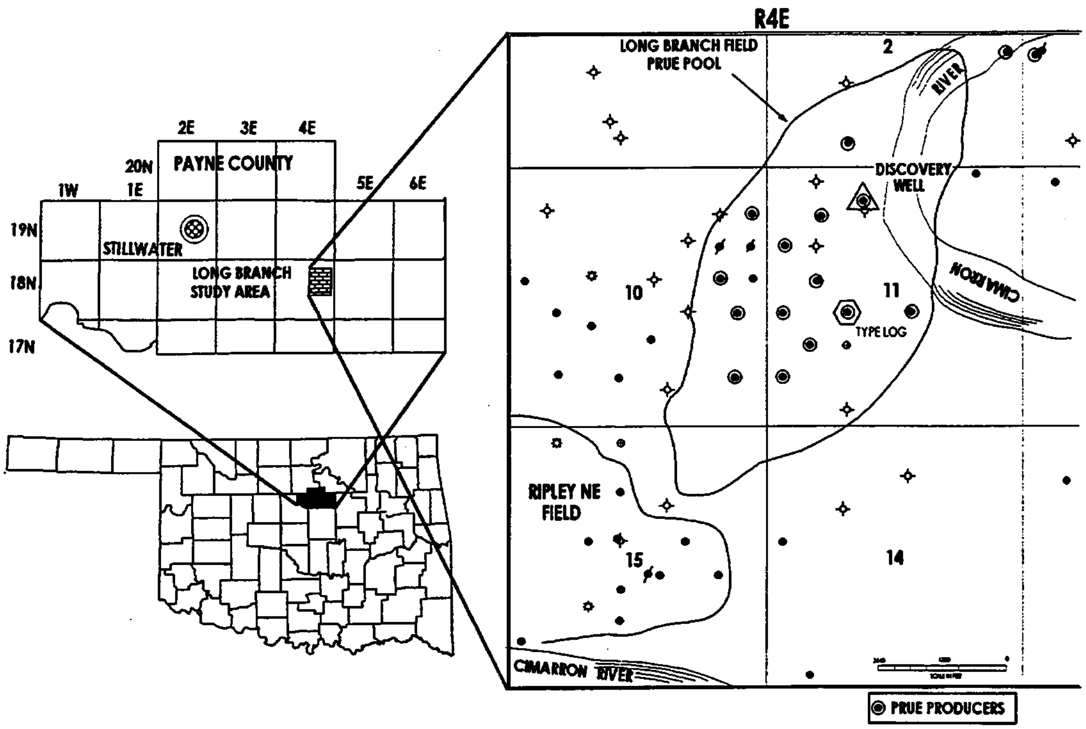

Figure 12. Generalized location map of the Long Branch field Prue oil pool, Payne County, Oklahoma.

were drilled to deeper targets and often had live oil shows in the Prue although the electric logs calculated wet. Completion of the discovery well was pursued by an alert consulting geologist who recognized the oil potential of the zone in spite of high water saturation calculations. The field opener tested at least 15 BOPD and subsequent drilling or recompletions led to 15 Prue oil wells with primary reserves of at least 200-300 MSTBO. The exact amount of oil production will never be known because it is commingled with production from several other pay zones.

The Prue reservoir sand in Long Branch field has a net thickness of 20-40 feet. The sandstone pinches out rapidly along the edges of the channel and is discontinuous up-dip to the northeast. The down-dip limit of the field is defined by an oil/water contact. The field is about 1½ miles long and about 2/3 mile wide.

The basic reservoir and engineering data for this field are shown in Table 12. Despite the large volume of oil in-place (~10 MMSTBO), only about 15-30MSTBO are expected to be recovered on a per-well basis. This very low recovery is due to the relatively high water saturation calculated to be 50-60%. The porosity (~16%) and permeability (~23 md) are relatively high, but without massive stimulation the Prue reservoir probably would not be productive.

TABLE 12 - Reservoir Properties for the Prue Sandstone in Long Branch Field Payne County, Oklahoma

Reservoir size	~800 acres
Spacing (oil)	20-40 acres
Oil/water contact	~ - 2475 feet
Gas/oil contact	none
Porosity	10-22% (avg. ~ 16%)
Permeability[1]	10-63 md (avg. ~ 23md)
Water saturation (calculated)	44-60%
Average Gas-Oil Ratio (GOR)	probably < 1000 SCF/BO
Thickness	15-42 ft (avg ~27 ft)
Reservoir Temperature	108° F
Oil Gravity	40-41° API
Initial reservoir pressure	NA
Initial formation-volume factor	1.25 (est from GOR, BHT, oil gravity)
Original Oil in Place (volumetric)	10,725,000 STBO
Cumulative primary oil production	undetermined, commingled with Peru
Estimated cumulative primary oil per well	15,000 - 30,000 BO
Recovery efficiency (oil)	undetermined, probably < 10%
Cumulative gas production	undetermined, commingled with Peru

[1] All wells have been fracture treated, possibly resulting in preferentially oriented enhanced permeability.

Waterflood simulations by Knapp and Yang indicate that the estimated volume of unproduced mobile oil is about 5.6 MMSTBO which is about 52% of the OOIP. Results of a 10-year model simulation show that this oil pool would be a very attractive secondary recovery operation using any alternative considered in this study. These include water flooding using existing wells versus water flooding with infill wells. The performance of these two scenarios is compared to a base case whereby current operations are maintained (Table 13). The incremental oil recovery due to water flooding is estimated to be as much as about 1,700 MSTBO or 20% OOIP. This is 4.7 times the amount that would be recovered by continuing the current operation conditions for 10 years.

TABLE 13 - Ten-Year Production Forecast Based on Reservoir Simulations

	Current operations	Waterflood with existing wells	Waterflood with infill wells
Cumulative oil production (mstb), 1/01/96	210	210	210
Expected cumulative oil production (mstb), 1/01/06	460	1,800	2,150
Incremental recovery from waterflood (mstb), 1/01/06	*	1,340	1,700
Cumulative water production (mstb), 1/01/06	1,700	12,000	15,250
Cumulative water injected (mstb), 1/01/06		14,350	18,100
Cumulative gas production (mmscf), 1/01/06	1,660	6,900	8,400
Maximum field oil production rate (stb/d)	70	700	900
Time at maximum oil rate (date)	1/01/06	2/01/00	5/01/00
Oil production rate (stb/d), 1/01/06	70	250	275

THE CLEVELAND AND PERU PLAYS

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Contributing authors: Bruce Carpenter, Roy Knapp, X. H. Yang
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Workshop site: Phillips Petroleum Research & Development Center, Bartlesville.
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The Peru and Cleveland sands are important oil-producing FDD plays in Oklahoma. They were combined for a dual workshop because of the relatively small number of operators attributed to each play in addition to the relatively small amount of oil production recorded during the past 17 years. The Peru sand is the informal subsurface name of the Englevale Sandstone and lies at least 100 feet beneath the Cleveland sand interval. The Cleveland sand also is an informal subsurface name and the sand interval is often comprised of an upper and lower sand horizon. The formal surface equivalents are the Tulsa and Jenks Sandstones, respectively.

The Peru Play

The Peru fluvial-dominated deltaic (FDD) play has centered on the Cherokee platform in northeastern Oklahoma (Fig. 13) and extends into southern Kansas. The play is limited by the outcrop on the east and by the depositional limit of the sand on the south and west. Peru is an informal subsurface term for the Englevale Sandstone in Kansas that lies within the Labette Shale of the Marmaton Group. In the subsurface terminology, the Labette is the shale interval between the Big Lime and the Oswego lime. The Peru sand is not as prolific as some of the other Cherokee sands, and has been overlooked as an objective reservoir. The Peru is quite shaley and commonly appears "wet" on resistivity logs; however, the Peru does produce oil and can be economic in spite of its poor appearance on wireline logs.

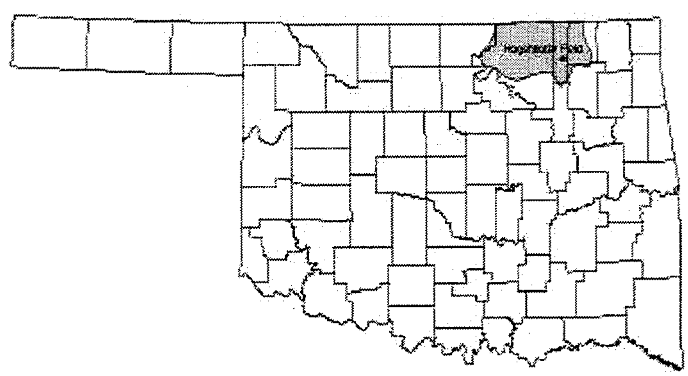

Figure 13. Generalized location map showing Peru FDD areas.

The shallow Peru sand lies in that part of Oklahoma where extensive oil reservoirs have been developed since 1904. Most wells in the area were drilled through the Peru zone and into the Bartlesville, therefore a lot of subsurface data and a large number of existing wells are available for calculating the oil potential of the Peru sand. The Peru sandstone reservoirs have been developed primarily in distributary-channel deposits of a fluvial-dominated deltaic environment. The reservoirs are generally stratigraphic traps where the sand is present on local structural noses or where the sand pinches out updip. Local uplift and sediment compaction also influence the localization of these oil reservoirs. The Peru sandstone in

Oklahoma covers an area only 42 miles north to south and 84 miles from east to west. However, most of the leases that produce from the Peru are in an area that extends only about 30 miles south from the Kansas state line and roughly 40 miles west from the outcrop. This area corresponds roughly to the eastern half of the sandstone area, where the Peru is generally thicker, up to 75 ft.

In terms of aerial extent and oil production, the Peru play is the smallest in the FDD series. During the past 17 years, estimated cumulative oil production is between 1 to 2 million barrels. The higher estimate includes commingled oil production whereas the lower estimate includes only Peru oil production. Typically, annual Peru oil production accounts for about 40-50 MBO. The play was developed primarily during the early 1900's and producing reservoirs are generally very shallow - less than 3000 feet.

Most fields having Peru production were developed in the early 1900's which inhibits any kind of detailed geologic field study. Log records are generally poor, and production records of individual wells are often incomplete or lost to history. Because of these problems, a suitable field study for waterflood modeling was not identified. Instead, an area of recent Peru production was identified and studied in as much as the data permitted. This area occurs within the Hogshooter field in central Washington county. The area of interest is confined to about 160 acres.

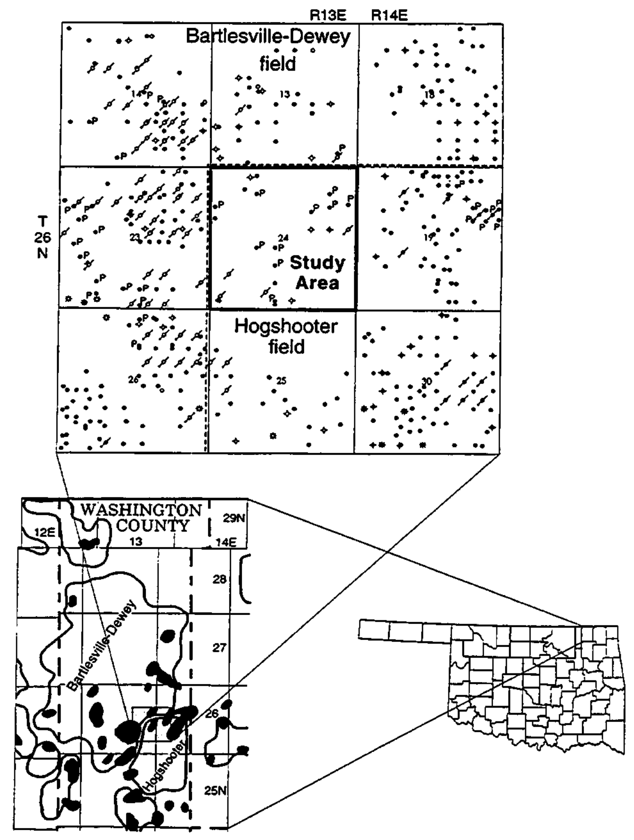

Figure 14. Maps showing the Hogshooter field, areas with Peru production (shown in black), and the Peru oil-reservoir study area in sec. 24, T. 26N., R. 13E., Washington County, Oklahoma. On the detailed map, large well spots with ***P*** denote wells that produce(d) oil from the Peru or from the Peru commingled with oil from another reservoir.

<u>Hogshooter Field</u>, in east-central Washington County, Oklahoma (Fig. 14) was discovered in 1906. The first oil production was from the Bartlesville sand, with an initial potential ranging from 225 to 500 barrels of oil per day (BOPD). Production from the Peru oil reservoir in sec. 24, T. 26N., R. 13E. was established in 1981 with the completion of the Chatauqua Oil, Inc., No. 2 Mayberry. The well had an initial pumping potential of 10 BOPD and 190 barrels of salt water per day (BSWPD) from perforations at 739-743 ft in a 50 ft thick Peru channel sandstone.

The reservoir is a local stratigraphic trap in a distributary-channel sandstone at the top of a progradational deltaic sequence. The seal for this stratigraphic trap is formed in part by the Labette Shale, which surrounds the Peru channel sandstone. Production was established during the early 1980's from a very thick channel sand (~80'). Most wells produced only a few barrels of oil per day and upwards to 275 barrels of water. The initial oil/water ratio varied from about 2-5% and because of this high water cut, the reservoir was essentially being produced under waterflood conditions during primary production. The reservoir lies at a depth of about 700 feet and hydrocarbon trapping results from structural nosing. Only the very upper part of the channel is perforated since the sand is mostly wet.

Total cumulative primary oil production from the Peru sand in the Hogshooter field is estimated to be about 42,000 barrels of oil. The original oil in place was not determined. Peru oil production was established in up to 8 wells. Reservoir properties (Table 14) are very good as the sandstone generally has relatively high porosity (~20%) and permeability (~28 md).

TABLE 14 - Reservoir Properties for the Peru Oil Reservoir in Hogshooter Field, Washington County, Oklahoma

Reservoir size	~230 acres
Spacing (oil)	10 acres
Oil/water contact	~ 40 ft above mean sea level
Gas/oil contact	none
Porosity	20%
Permeability	28 md
Initial water saturation	<56%
Thickness (net sand in reservoir)	48 feet average
Reservoir temperature	85° F
Oil gravity	35° API
Initial reservoir pressure	unknown
Initial formation-volume factor	unknown
Original Oil in Place (volumetric)	unknown
Cumulative primary production (Peru-only)	42,040 BO (13 wells)
Recovery efficiency	unknown
Cumulative primary gas production	no data

However, because of the strong water drive and high water cut during production, this reservoir is not suitable for secondary water flooding since the reservoir is being water-flushed concurrent with primary production (an induced water flood).

The Cleveland Play

The Cleveland sand is an informal subsurface term first used by drillers at the Cleveland oil field in eastern Pawnee County. The Cleveland sand interval consists of as many as three persistent, but not continuous bodies of sandstone. The lowermost ("lower"Cleveland) occurs most widely and commonly is the thickest. The upper two sandstone bodies are less widespread, but are significant hydrocarbon reservoirs locally. It is generally recognized that the Dawson coal splits the upper and lower Cleveland sands.

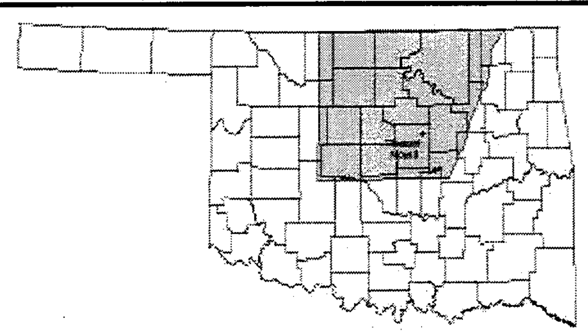

Figure 15. Generalized location map showing Cleveland FDD areas.

This play occurs throughout much of north central Oklahoma (Fig. 15). It consists largely of fluvial and delta front (marine) sediments that prograded in a westerly direction. This is very unlike many of the Cherokee plays that advanced in a southerly direction. Although FDD components constitute a large part of the Cleveland interval, there are scattered areas of sandstone deposition that are probably entirely of marine origin rather than deltaic. These areas are primarily located in western Oklahoma.

Over the past 17 years, Cleveland production was reported from 158 fields and the total estimated oil production is about 12,500,000 barrels (Table 15). During the past six years, annual production was typically about 500 MBO. The play was developed primarily during the early 1900's but is now more often regarded as a secondary objective. Field mapping and regional production data indicate that there are still local areas containing significant oil potential in this play. Cleveland reservoirs are generally shallow - less than 6000 feet.

Table 15. Crude Oil Production from Cleveland Sand Reservoirs, 1979-1995

Reservoir	Leases reporting[1]	Cumulative oil	Average bbl/lease	Other leases[1,2]
Cleveland sand	326	11,445,443	35,109	264
"Jones"[3] sand	56	999,696[4]	17,852	34

1 Average number of leases during the time frame, 1979-95.
2 Commingled production with that from other formations.
3 "Jones"sand is a local equivalent of the Cleveland.
4 "Jones"sand reservoirs include production from Cleveland sand and other formations.
SOURCE: Natural Resources Information System (NRIS) oil and gas production data base

Pleasant Mound Field. Cleveland sand reservoir is in northeastern Lincoln County, secs. 10,11,14,15 and secs. 22-26, of T. 16N., R. 6E. The study area consists of ~2,000 productive acres that are bounded by oil-water contacts on the west and by the sand-body limits on the east. The southern boundary is assumed to be a no-low boundary. The oil-bearing Cleveland sand appears to have been deposited in three layers: B, C, and D.

The Cleveland sand was discovered by the Nadel & Gussman No. 1 Alice Teters well in September 1956. Twenty-six additional wells were drilled and completed in zones B and C during the next three years. Most of the production has been from zone B, which was perforated in all 36 producing wells. Total cumulative oil production from the Cleveland sand prior to water flooding in Pleasant Mound field is estimated to be 400,000 BO which is about 3% of the original oil in place (13.6 MMSTBO). In 1960, because of a steep decline in oil production, the Pleasant Mound Cleveland sand unit was formed. Initially, there were six injectors and up to 18 producing wells although not all of the producing wells were completed in the zone being water flooded. Water was injected at a rate of about 100-400 BWPD per well. However, response to water injection did not occur for nine years until 1970 at which time four more injectors were added. The biggest response in oil production occurred the following year when it more than tripled to about 2000 BO/month in 1971. By the end of 1995, primary plus secondary oil production totaled about 860,000 BO, the field oil-production rate was <2 BOPD and the water cut had reached 99%.

The original oil in place in the Pleasant Mound Cleveland sand reservoir was estimated to be 13.6 MMSTB. Only ~6% of that amount has been recovered after 40 years of primary and waterflooding production. The estimated volume of unproduced mobile oil in this field (~6.8 MMSTB, or 50% of OOIP) provided a strong motivation for considering future oil recovery opportunities. The reservoir lies at a depth of about 2,200 feet, and hydrocarbon trapping results from an up-dip stratigraphic pinch-out of net sandstone. Reservoir properties are very favorable for secondary water flooding since the sandstone generally has relatively high porosity (~20-23%) and permeability (~50-130 md). These data are summarized in Table 16.

TABLE 16 - Reservoir Properties, Cleveland Sand Reservoir, Pleasant Mound Oil Field, Lincoln County, Oklahoma

Estimated properties	Zone B	Zone C	Zone D
Porosity	23%	20%	20%
Permeability	130 md	50 md	50 md
Average Gross Pay	20 ft	20 ft	25 ft
Average Net Pay	10 ft	15 ft	13 ft
Initial Water Saturation	32%	32%	32%
Initial Bottom-Hole Pressure	950 PSIA	950 PSIA	950 PSIA
Initial Gas-Oil Ratio	385 SCF/STB	385 SCF/STB	385 SCF/STB
Initial Formation-Volume Factor	1.20 RB/STB	1.20 RB/STB	1.20 RB/STB
Reservoir Temperature	106° F	106° F	106° F
Oil Gravity	48° API	48° API	48° API
Specific Gas Gravity	0.8	0.8	0.8
Initial Oil in Place	7.5 MMSTB	5.6 MMSTB	0.6 MMSTB
Initial Gas in Place	3,800 MMSCF	3,000 MMSCF	220 MMSCF

Table 17 summarizes the reservoir's oil production history as well as projected outcomes for several different secondary oil recovery development cases based on the models developed by Knapp and Yang. Waterflood modeling indicates that unproduced mobile oil amounts to about 6.8 MMSTBO or 50% or the OOIP. Various secondary recovery scenarios were examined which indicate that up to 2,800,000 STBO could be recovered in 10 years which is about 3.3 times the recovery during the past 40 years. The various enhanced recovery scenarios include the recompletion of several wells for injection (for a total of 14 injectors), and varying water injection rates and bottom-hole pressures (300 vs. 1800 psi - Options 1 and 2, respectively). The base case assumed that there were no changes in field development and well operating conditions.

TABLE 17 - Oil Recovery Comparisons for Different Development Cases, Cleveland Sand Reservoir, Pleasant Mound Oil Field, Lincoln County, Oklahoma

	Primary & Water-flooding (12/1995)			Base (12/2005)			Recompletion -Option 1 (12/2005)			Recompletion -Option 2 (12/2005)		
Formation	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (MSTB)	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr ((MSTB)	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (MSTB)	Cum Oil (STB)	Rec. Factor (%)	Cum Wtr (MSTB)
Zone B	835,000	11.1	2,700	940,000	12.5	2,900	1,550,000	21	11,000	2,000,000	26.7	40,000
Zone C	25,000	0.4	400	30,000	0.5	500	470,000	8.4	380	650,000	11.6	2,000
Zone D	0	0	0	0	0	0	80,000	13	20	150,000	25	1,000
Total	860,000	6.3	3,100	970,000	7.2	3,400	2,100,000	15.5	11,400	2,800,000	0.6	43,000

THE RED FORK PLAY

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Contributing authors:	Kurt Rottmann, Roy Knapp, X. H. Yang
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Workshop sites:	Postal Service Technical Training Center, Norman, and the Phillips Petroleum Research & Development Center, Bartlesville.
Publication:	Oklahoma Geological Survey SP 97-1, Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Red Fork Play.

The Red Fork sandstone has been, and continues to be, one of the main producers of oil and gas in Oklahoma. Unlike some of the other shallower Cherokee sands, such as the Prue and Skinner, the Red Fork is relatively clean. Therefore, Red Fork oil potential was generally not overlooked because of a shaley or wet appearance on wireline logs. Thus, during the past fifty years numerous fields have been discovered and developed as a result of deliberate exploration for the Red Fork.

Figure 16 shows the generalized distribution and depositional facies of the Red Fork sandstone. The Red Fork interval is mostly shale and sandstone that lies between the Pink lime and the Inola Limestone. In most places, the entire interval is ~100ft thick and contains one or two 10- to 50- ft thick sandstones with an occasional thin limestone or coal bed. Sandstones in the Red Fork interval are mostly fine to very fine grained, with some medium-grained sandstone. In general, the Red Fork FDD system has a northerly source and advanced to the south and west. Sandstone in the Red Fork interval originated from a major fluvial system that advanced across much of the Cherokee Platform in a southerly direction.

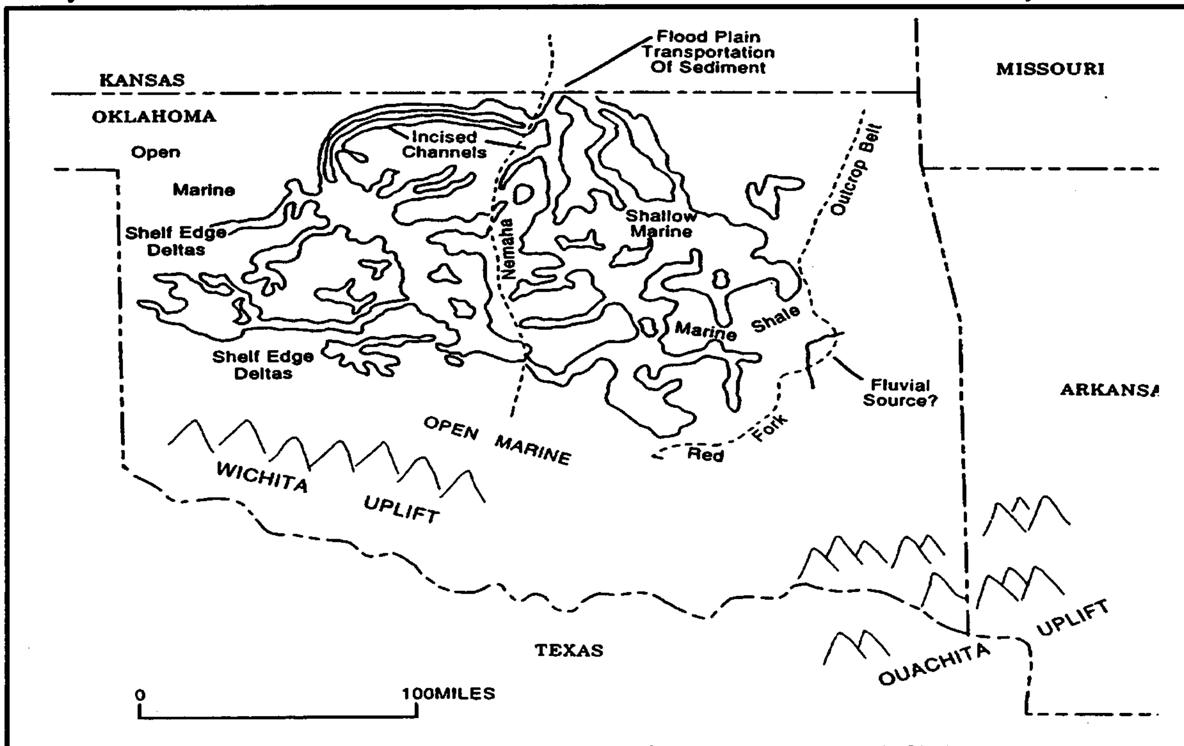

Figure 16. Generalized distribution and depositional environments of the Red Fork sandstone in Oklahoma.

The Red Fork sandstone is one of the most widespread Cherokee plays in Oklahoma. A regional isopach map of the interval from the top of the Pink lime to the top of the Inola Limestone reflects the location and the geometry of the basins and platform areas that existed during the deposition of the Red Fork (Fig. 17). The thickness of the Red Fork interval was apparently controlled mostly by the configuration of the Cherokee platform, the Nemaha fault zone, the central Oklahoma uplift, and Anadarko basin. The Red Fork interval is relatively thin (≤100ft thick) and relatively uniform in thickness throughout much of central and northeastern Oklahoma. This indicates that Red Fork deposition was significantly attenuated along the Nemaha uplift and possibly eroded. The relatively uniform thickness of the Red Fork interval also suggest that the depositional gradient was relatively low on the Anadarko shelf and Cherokee platform. This is in sharp contrast to the Anadarko Basin, where the Red Fork interval thickens considerably over a short distance.

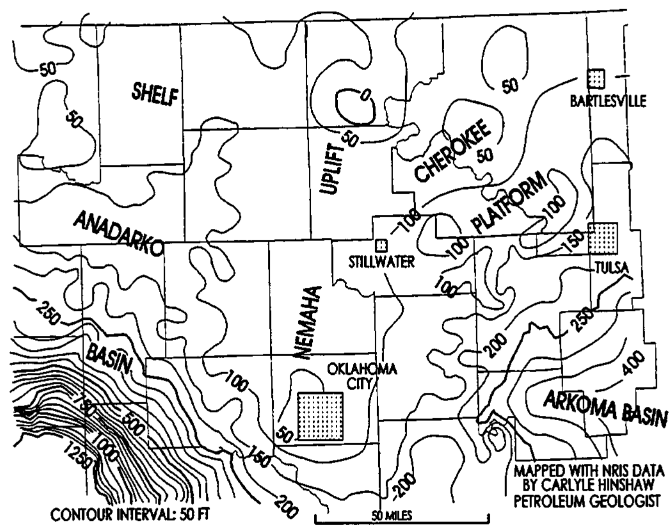

Figure 17. Regional isopach map of the interval from the top of the Pink lime to the top of the Inola Limestone (Red Fork interval plus the Pink lime), Oklahoma. Contour interval is 50 ft.

__North Carmen Field__ is located in Alfalfa County in northwestern Oklahoma (Fig. 18). The field is about 60 miles west of the Nemaha uplift, in the area commonly referred to as the Anadarko Shelf Province. Early wells drilled in N. Carmen were completed in the Mississippi lime in 1965. The Red Fork in these early wells were shaley.

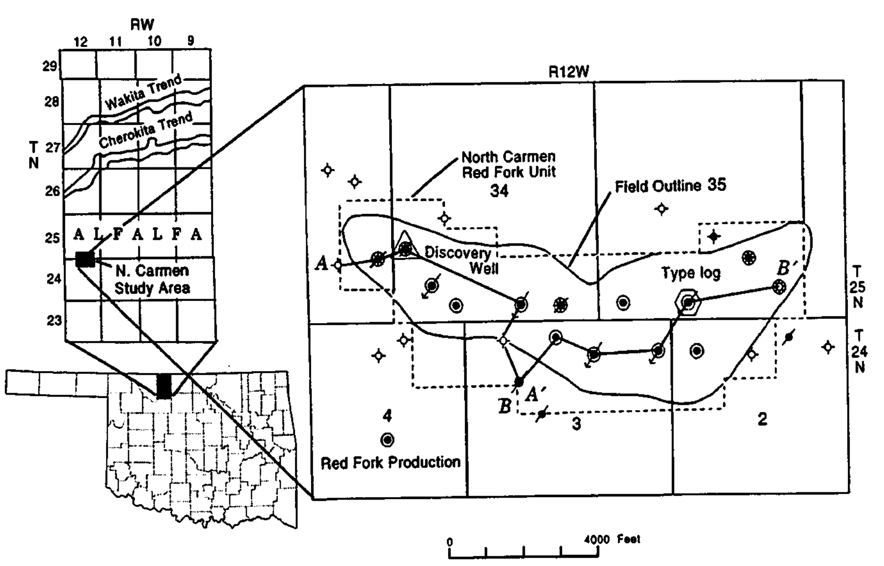

Figure 18. Map showing location of the N. Carmen Field in southwestern Alfalfa County, Oklahoma. The field boundary is shown by the solid line; the N. Carmen Red Fork Unit boundary is shown by the dashed line. The Cherokita and Wakita trends also produce from the Red Fork sand.

In December 1984, Duncan Oil drilled the field opener for the Red Fork oil pool. The No. 1 Zoa (SW¼ NW¼ SW¼ sec. 34 T. 25N., R. 12W.) had an initial potential flowing 108 BOPD, 344 MCFGD, and no water from 14 ft. of Red Fork sandstone. During the next year, nine additional Red Fork wells were drilled in the area east of the discovery well. By mid-1986, 14 wells had been completed in the Red Fork.

The N. Carmen Red Fork has an oil gravity ranging from 40° to 50° API. The lighter oil is found structurally lower in the reservoir. N. Carmen is fully developed on 40 acre spacing. Most of the wells were shut-in during the early 1990's when individual well production fell only to a few barrels of oil per day. In late 1995, the field was unitized by Ensign Oil and Gas and a waterflood was initiated.

Regional dip of the Pink lime in the study area is to the south at ~50ft/mi. In the study area, the regional southward dip is interrupted by a pronounced northeast trending trough that plunges to the south in the eastern part of the study area, and a smaller northwest trending trough in the western part of the field. These deviations from the regional structure are probably the effects of small-scale basement faulting. Because there is no dominant structure feature as incentive for exploratory drilling, this field was discovered by extending the known geologic trend of the Red Fork channel that was delineated further to the west in the early 1980's.

The estimated cumulative oil and gas production from the Red Fork in N. Carmen field from December 1984 through June 1996 is 415,082 BO and 2,315685 MCFG. The peak in annual oil production was in 1985 when 10 wells produced 166,375 BO; average daily production was 46 BOPD per well. In 1988, 12 wells were producing and production had fallen to 17,931 BO; 4 BOPD per well.

Long Branch Field, located in east-central Payne County in north-central Oklahoma (Fig. 19). This is the same field area in which a Prue reservoir had been the subject of a previous study and workshop (see Figure 11). The first commercial Red Fork well was completed in November 1983. Statex Petroleum's No. 1 Snyder, (sec. 10 T. 18N., R. 4E.) was completed in about 6ft of net Red Fork sand and had an initial flowing potential of 238 BOPD, 100 MCFGPD, and no water. During the next year development in the area progressed to the northwest where a much thicker Red Fork sand was encountered. As of April 1996, nine wells had been completed in the Red Fork pool; however, the only two Red Fork wells still active were making only a few barrels of oil per day. Because of the shallow depth and well spacing patterns, this field appears to be an excellent candidate for a waterflood.

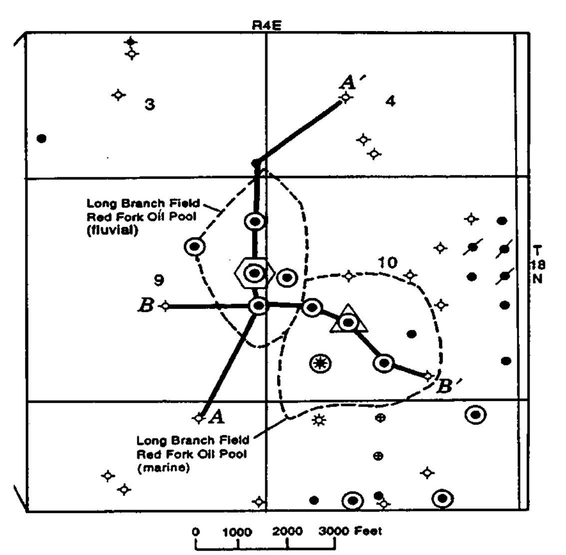

Figure 19. Long Branch study area. The field outline is differentiated between fluvial and marine reservoir facies as determined from well logs.

Regional dip in the area surrounding Long Branch Field is to the west-southwest toward the Anadarko basin at ~50ft/mi. The Red Fork channel sandstone that is productive is interpreted to be a point bar deposited within a meandering river of a flood plain. The point bar sandstone was interpreted mainly from the character of the gamma ray and resistivity logs. The sandstone has a fining-upward textural profile that includes shale breaks in the upper half of the sandstone. The point bar sands contain a major portion of the oil within the Red Fork oil pool in Long Branch field. Productive marine sandstone is interpreted to have been deposited on a shallow marine shelf, as bars, or poorly developed shoreface. Estimated cumulative oil and gas production from the Red Fork in Long Branch field from November 1983 through April 1996 was 247,206 BO and 158,849 MCFG. The principal drive mechanism is interpreted to be a solution gas expansion rather than a water drive. Wells in this field were diminished to strippers by the late 1980's when the average daily oil production was only 2-3 BOPD.

THE TONKAWA PLAY

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Workshop date:	July 9, 1997
Workshop site:	Postal Service Technical Training Center, Norman, OK.
Publication:	Oklahoma Geological Survey SP 97-3, Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Tonkawa Play.

The Tonkawa Play has been of continued interest for many operators and geologists for a long time, but recently has become very active in western Oklahoma. The renewed interest in the Tonkawa centers in the Anadarko Shelf and Basin areas where production is prone to gas from marine sands. Although portions of north central Oklahoma have significant areas containing FDD deposits, only scattered areas within the FDD portion of the play produce oil. (Figure 20.) Because of the nature of hydrocarbon distribution patterns within the Tonkawa play and the high interest in the predominantly gas prone areas of the state, it was decided to complete the Tonkawa play in two parts: FDD oil and non-FDD gas. The funding support for the effort was divided between the FDD (fluvial oil reservoirs) and the Petroleum Technology Transfer Council projects (marine gas reservoirs). The Oklahoma Geological Survey SP publication however, included only information and maps relevant to Tonkawa FDD (oil) play. Information concerning the Tonkawa gas play in the predominantly marine facies of the Anadarko Basin is available as an OGS open file report.

Relatively little has been published about the Tonkawa play, and the interpretation supporting FDD deposition is documented in only a few thesis and by well log evaluations by the primary author. The basic patterns of deposition appear to be primarily FDD along the outcrop belt and into the shallow subsurface. In western Oklahoma, the Tonkawa is interpreted to be primarily of marine origin although some investigations indicate that lower delta-plain and/or deep marine deposition took place. These contradictory interpretations have provided an incentive to more accurately evaluate the regional depositional environment of the Tonkawa play and better identify the principal sandstone trends.

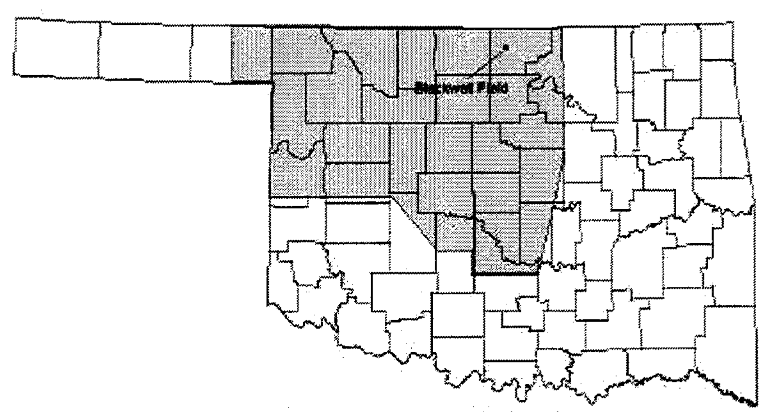

Figure 20. Generalized location map of the Tonkawa play.

The Virgilian age sandstones of the Tonkawa play are the youngest of the fluvial-deltaic reservoirs to be investigated in the FDD workshops, with drilling depths of about 2,200-4,400 ft. Tonkawa reservoirs have produced oil and gas for 76 years in Oklahoma. The historical record of that production is incomplete; however, from 1979 through 1996, 29 fields produced oil from the Tonkawa sand in the area of fluvial-dominated deltaic sand deposition.

The Tonkawa play consists of the widely occurring, uppermost sandstone unit below the Haskell Limestone. Several sub-commercial plays have been found above and below the Haskell, but are minor in comparison to the Tonkawa production. The Tonkawa and related sand units are bounded below by the Wildhorse Limestone and equivalents. The regional structural dip is westward to southwestward at about 300 ft/mi. The accumulation of commercial amounts of oil and gas in Tonkawa sand reservoirs is associated mainly with the Nemaha uplift and Nemaha fault zone. Fault controlled structures are common in the area, and anticlines associated with basement-rooted faults have trapped hydrocarbons in many of the producing fields.

Blackwell Field's Tonkawa oil reservoir lies in secs. 9 and 10, T. 27N., R. 1W., and secs. 3 and 4 in T. 27N., R. 1W., Kay County, Oklahoma (Fig. 21). The Tonkawa sand in this field is at depths of ~2,300 ft or ~1,300 ft subsea. Its average thickness is ~35 ft, and its aerial extent, ~850 acres. Production from the Tonkawa was first established in 1923 in the Blackwell Oil and Gas Co. No. 1 Humphrey (SE¼ NW¼ SW¼ sec. 10 T. 27N., R. 1W.). The well was completed with an initial flow of 220 BOPD. The field was expanded with the drilling of 15 additional Tonkawa producers developed on 10-acre spacing from 1923 through 1941. For this time period, it is not known how much oil was recovered from these wells, thus the production history is incompletely known for the reservoir.

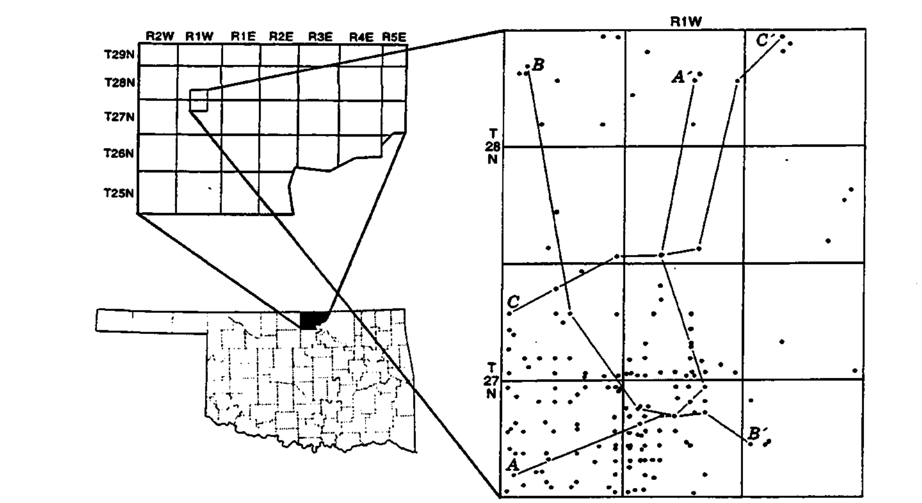

Figure 21. Generalized location map of Blackwell field study area, Kay County, Oklahoma. Lines of cross-sections included in the study are indicated.

The "B"sandstone, the main oil and gas reservoir, has an average porosity of 24% with an oil gravity of 44° API. Bottom-hole temperature was measured at 100°F, and a bottom-hole pressure of 950 PSI. Drill-stem test results from early in the life of the reservoir and from more recent tests indicate the same BHP. The persistence of reservoir pressure without pressure maintenance indicates the reservoir has a very strong water drive. Many early wells were completed flowing oil naturally. The original oil in place (OOIP) is calculated to ~9.1 million stock barrels of oil (MMSTBO). The reported primary production from 1956 through 1995 is 1.282 MMSTBO, which is a recovery factor of 14%.

THE BARTLESVILLE PLAY

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Contributing authors:	Richard Andrews, Roy Knapp, X. H. Yang
Workshop dates:	October 29 and 30, and November 12, 1997
Workshop sites:	U.S. Army Corps of Engineers Facility, Tulsa; Phillips Petroleum Research & Development Center, Bartlesville; Postal Service Technical Training Center, Norman.
Publication:	Oklahoma Geological Survey SP 97-6, Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Bartlesville Play.

Oil reservoirs in the Bartlesville sandstone were the foundation for the dominance of Oklahoma as an oil producing state. On April 15, 1897, Cudahy Oil Co. No. 1 Nellie Johnstone, a Bartlesville sand oil well, opened the first commercial oil field in Oklahoma. Subsequent discoveries of Bartlesville oil fields made Oklahoma the leading oil producing state from statehood in 1907 until 1923. The Bartlesville play is situated on the Cherokee platform of northeastern Oklahoma (Fig. 22). The play is limited on the east at the outcrop, where the Bartlesville surface equivalent is the Bluejacket Sandstone, and on the south by its outcrop along the front of the Ouachita Mountains uplift. To the west the play is bounded by the limit of deposition of sand or onlap of the Bartlesville interval around the Nemaha uplift. Southwest of the Cherokee platform, the Bartlesville interval either was not deposited or was removed by erosion on the Oklahoma City uplift. Only marine deposits occupy the Bartlesville interval of the Anadarko basin, outside of the play area.

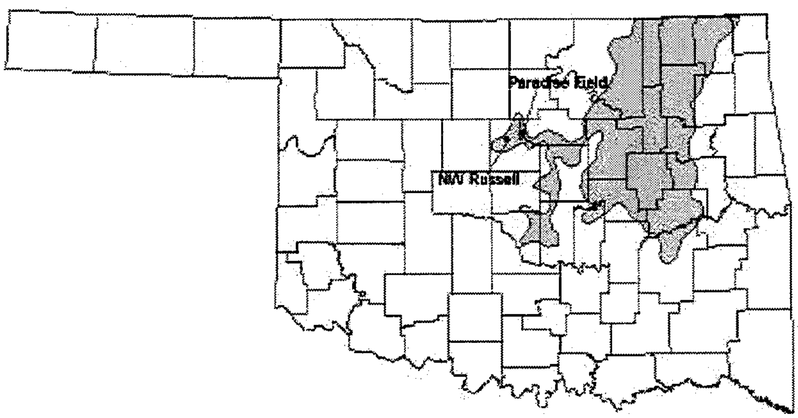

Figure 22. Generalized location map of the Bartlesville play.

The Bartlesville sand increases in depth from the outcrop on the east to ~2,400 ft at the western sand limit in southeastern Osage County. The depth of the Bartlesville sand increases to ~4,800 ft in the lower Anadarko shelf area. The regional dip of the Bartlesville sand zone is to the west from the Ozark uplift in the northeastern Oklahoma. The thickness of the Bartlesville interval is generally controlled by intensity and duration of the depositional processes and the spatial relationship to structural provinces. The interval thickens bainward of the Cherokee platform and away from the Nemaha uplift. The sand is up to 200 ft thick in places along the main transport direction. The Bartlesville interval generally thins from the southeast to the northwest, where it onlaps older strata. It is absent over some the structural features in northeastern Oklahoma, either by nondeposition or erosion.

Paradise Field is located in southwestern Payne County in north-central Oklahoma. The field area is about 25 miles east of the Nemaha uplift on the Cherokee platform. Paradise field produces oil and gas from several types of Bartlesville sand deposits, including various kinds of channel deposits such as point bars in addition to tidal-mouth bars. Oil production was first established in the Paradise study area in the 1950's with the completion of two wells in the northern part of sec. 34, T.18N., R.1E. These wells were completed in the marine facies of the Bartlesville sand for up to 174 BOPD. In an effort to extend the original Misener oil production to the south, Canadian Exploration drilled the No. 3 Downey well (SE¼ SW¼ SE¼ sec. 33, T.18 N., R.1 E.), and accidentally discovered the Bartlesville oil pool in Paradise field. This well was completed in March 1986 and had an initial flowing potential of 290 BOPD, 133 MCFGPD and 2 BWPD from 30 ft of net Bartlesville sandstone. A total of 13 wells were completed in the Bartlesville reservoir, with oil gravities ranging from 34° to 40° API.

Paradise field is fully developed on 10-20 acres spacing. The peak in annual oil production was in 1990, when 12 wells produced 83,866 BO averaging 20 BO per well. In March 1994, the eastern part of the field was unitized by Pennacle Oil, and waterflood was initiated. In mid-1995 the first significant response in oil production was measured. The estimated oil and gas production from the Bartlesville in Paradise field from March 1986 through July 1996 is 427,752 BO and 450,718 MCFG (Table 18).

TABLE 18. - Oil- and Gas-Production Statistics for the Bartlesville Sandstone in Paradise Field, Payne County, Oklahoma

	Number of wells		Annual production		Average	Average monthly production per well		Average daily production per well		Cumulative production	
Year	Oil	Gas	Oil BBL	Gas MCF	GOR	Oil BBL	Gas MCF	Oil BBL	Gas MCF	Oil BBL	Gas MCF
1986[a]	2	1	30,349	11,348	374	1,686	1,135	56	38	30,349	11,348
1987[a]	4	2	53,564	25,688	480	1,275	1,284	43	43	83,913	37,036
1988[a]	10	5	80,429	52,661	655	1,072	1,699	36	57	164,342	89,697
1989	10	6	80,308	87,824	1,094	669	1,220	22	41	244,650	177,521
1990	12	8	83,866	78,619	937	612	1,062	20	35	328,516	256,140
1991	12	9	38,399	91,236	2,376	267	861	9	29	366,915	347,376
1992	12	9	22,321	48,640	2,179	155	450	5	15	389,236	396,016
1993	12	9	16,697	32,111	1,923	116	297	4	10	405,933	428,127
1994[b]	11	8	8,445	19,011	2,251	64	198	2	7	414,378	447,138
1995	11	7	6,577	3,580	544	50	37	2	1	420,955	450,718
1996[c]	9	0	6,797	0	0	63	0	2	0	427,752	450,718

[a] Includes wells having only a partial year's production. [b] Unitization occurred January 1994. [c] Production through July 1996.

Northwest Russell Field is located in Logan County in north-central Oklahoma (Fig. 23). The field area is about 11 miles east of the Nemaha uplift on the Cherokee platform. NW Russell field produces oil and gas from several reservoirs, although the Bartlesville sand, Mississippi lime and the Oswego lime are the principal supply sources. Oil and gas production from these reservoirs is generally commingled, and only a few wells produce from a

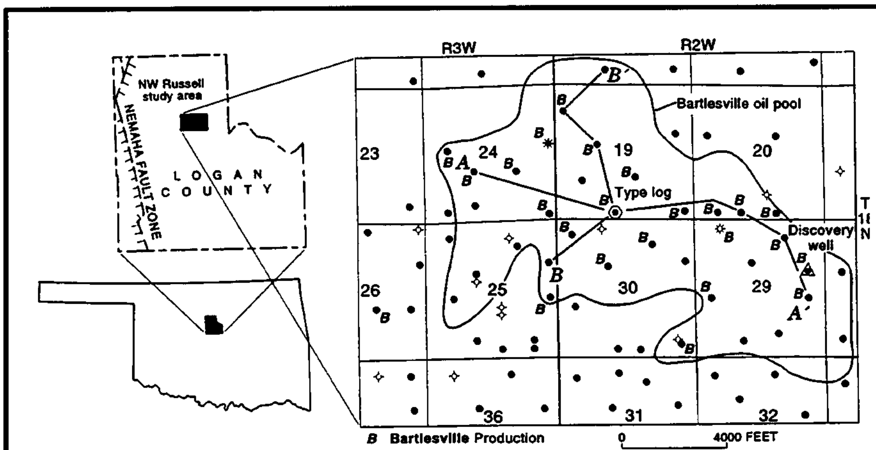

Figure 23. Map showing location of the Bartlesville oil pool in the NW Russell field area, Logan County, Oklahoma.

single-zone completion. Oil production from the Bartlesville sand was first established in the field when Bobby Darnell drilled the No. 3 Brown in sec. 29, T. 18N., R. 2W. The NW Russell Bartlesville oil pool probably was discovered in a deliberate effort to extend known productive fluvial trends farther to the west. This same trend is productive in Paradise field, 12 miles to the east. The discovery well was completed in 1977 with an initial flowing potential of 18 BOPD from 8ft of net Bartlesville sandstone. A total of 27 wells were completed in the Bartlesville with oil gravities ranging from 39° to 42° API.

NW Russell field is fully developed on 80-acre spacing. Most if not all wells continue to produce small amounts of oil and gas, and the field has never been developed for secondary oil recovery. The cumulative oil and gas production volumes from the Bartlesville are unknown due to the commingling of production from several reservoirs. Three wells have single zone Bartlesville completions and are presented in Table 19. These wells typically have sand development in the non-channel facies with about 17,500 BO and 176,000 MCFG per well.

TABLE 19. - Annual Production and GOR for Three Wells Completed Exclusively in the Bartlesville Sandstone

Year	SE SW 20,18N-2W #1 Dunsmore			NE SE 29,18N-2W #2 Acton			SE NW 29,18N-2W #1 Miller		
	Oil (BBL)	Gas (MCF)	GOR	Oil (BBL)	Gas (MCF)	GOR	Oil (BBL)	Gas (MCF)	GOR
1978	0	0		0	0		0	0	
1979	5,214	15,134	2,903	4,859	10,376	2,135	6,593	22,465	3,407
1980	2,523	2,016	799	6,868	28,952	4,215	2,911	45,004	15,460
1981	1,322	5,912	4,472	2,757	29,963	10,868	1,330	32,959	24,781
1982	750	6,070	8,093	1,462	21,921	14,994	724	15,370	21,229
1983	532	8,014	15,064	1,263	14,615	11,572	757	14,122	18,655
1984	691	4,578	6,625	866	17,560	20,277	738	13,806	18,707
1985	205	3,992	19,473	864	16,086	18,618	540	11,424	21,156
1986	300	2,096	6,987	574	14,992	26,118	543	11,113	20,466
1987	260	2,203	8,473	345	9,720	28,174	360	10,321	28,669
1988	262	1,631	6,225	517	10,268	19,861	352	8,205	23,310
1989	332	2,434	7,331	351	10,520	29,972	181	8,712	48,133
1990	396	1,774	4,480	350	9,597	27,420	364	8,107	22,272
1991	364	1,830	5,027	350	8,668	24,766	178	7,417	41,669
1992	227	1,425	6,278	126	5,675	45,040	180	6,519	36,217
1993	264	1,350	5,114	333	7,538	22,637	179	5,589	31,223
1994	397	1,730	4,358	87	5,525	63,506	175	5,633	32,189
1995	0	1,399		0	6,656		171	3,712	21,708
1996	327	1,064	3,254	0	5,518		0	0	
Cumulative	14,366	64,652	4,500	21,972	234,150	10,657	16,276	230,478	14,161

Industry Responses

Since the inception of the workshop program in 1995, industry responses to the program have been very positive. In short, this program has been described by numerous industry representatives as the most valuable program that the Oklahoma Geological Survey has ever implemented. The operator registration statistics for the various workshops support this assertion, as shown in Table 20.

TABLE 20. - Summary of FDD Play Workshops Operator Responses

Play	Workshop Dates & Locations	Total Regis-trations	# of play operators	Registered Play operators	Registered Operators not in play	Total Workshop Operators
1. Morrow	June 1 & 2, 1995 Norman	215	604	95	5	100
2. Booch	September 11,1995 Muskogee	128	432	31	20	51
3. Layton & Osage-Layton	April 17, 1996 OKC	103	342	21	25	46
4. Prue & Skinner	June 19 & 26, 1996 OKC & Bartlesville	201	1599	72	23	95
5. Cleveland & Peru	October 17, 1996 Bartlesville	85	516	24	14	38
6. Red Fork	March 5 & 12, 1997 Norman & Bartlesville	195	1478	69	29	98
7. Tonkawa	July 9, 1997 Norman	101	347	23	25	48
8. Bartlesville	October, 1997 Tulsa, Bartlesville, & Norman	183	1420	49	31	80
	TOTALS:	**1,211**	**6,738**	**384**	**172**	**556**

The 1,211 total workshop registrations reflect 584 individuals, many with multiple registrations. Of the 584 individuals:

- 355 (61%) are from active operating companies, based on a comparison of company names to gross production tax records
- 145 (25%) are from other industry interests such as service companies, or are "consultants" (31) or "independents"(30), that could not be linked to the gross production tax records.
- 44 (8%) are OGS, University, and program staff members
- 40 (7%) are from other State and Federal agencies, and from "data suppliers"such as the OCGS and PI/Dwights.

Excluding the OGS, University, and program staff members from consideration, of the remaining 541 individuals,

- 181 (33%) have attended at least two of the workshops
- 92 (17%) have attended three or more workshops
- 41 (8%) have attended four or more workshops
- 21 (4%) have attended five or more workshops.

**All of these statistics are based on registration records and a post hoc linking to the gross production records. Because of this, it is possible that some company identifications and operator designations have been missed. Therefore, these should be considered "conservative" estimates of the operator contacts through the FDD program.

By the third workshop of the FDD series, an attendee workshop evaluation process was implemented. At each of the workshops given during 1996 and 1997, attendees were asked to complete evaluation forms reflecting their assessments of the materials and presentations.

For all of the plays, attendee evaluations were overwhelmingly positive, with average scores ranging from "very good"to "great"on nearly every item in the evaluation form. A summary of the compiled evaluations for each of the plays is provided in Appendix A.

Task 3: Professional Outreach

Several levels of professional outreach were identified as part of this overall project effort.

Technical Advising: Following each of the workshops that were held in the program, the workshop participants (particularly the play leaders and the engineering staff) were called on to serve in an advisory role to respond to various industry inquiries. Operators called with specific questions about how to best manage a property they may have in the play. In this role, the project staff typically could not fully research the property to recommend a course of action, but generally were able to direct people towards the kinds of information and issues they should address. These contacts were fruitful not only for industry, but also for the project staff as they obtained feedback on the value of the publications and workshop materials.

Reservoir Characterization and Simulation Studies: These studies were conducted in cooperation with the operators of the selected reservoirs, with the goal of identifying opportunities for increasing recovery from those reservoirs. Operators were selected for these studies based on the quality of data they had for the reservoir, their willingness to participate and contribute resources to the study, and their willingness to allow the project results to be published and otherwise made available to industry.

A primary goal for these reservoir characterization studies was to develop methodologies that are affordable, understandable, and usable for the small independent oil operator. While the data collection for these selected reservoirs was in far greater detail than for other reservoirs in the plays, it was still at a "minimized" level of detail relative to comprehensive reservoir studies that are performed in research facilities or by major companies in industry. The typical reservoir for these studies had about 15 to 40 wells, and fields with current production data and modern well logs were preferred. Lithology, estimates of the original hydrocarbons-in-place, and production profiles (oil, gas and water) for the reservoir were important components for the reservoir characterization. When necessary, algorithms were developed to estimate water and gas production from the reservoir, and to describe the geologic framework. The level of precision resulting from these studies was necessarily limited, but accomplished the basic goals of helping operators target the remaining resource.

Professional Activities: Information on the FDD project activities was distributed through a number of professional outlets. During the project, OGS displays provided information about the FDD program at events such as the annual meetings of the American Association of Petroleum Geologists and the Geological Society of America, and at various regional and local meetings and events. Additionally, the play leaders from each of the work shops were periodically called upon to present short summaries of their work in area professional gatherings, such as the monthly meetings of the Oklahoma City Geological Society.

VI. CONCLUSIONS

There is no direct way to measure the impact that this program has had on the volumes of FDD oil production in Oklahoma. Throughout Oklahoma, as in the rest of the domestic petroleum industry, oil well abandonments have continued to increase and production has continued to decline throughout the five years of the program. There is no way of knowing what that decline would have been if this program had not been implemented. Furthermore, most of the volumetric impacts of this program will in fact be realized in future years. If this program has served its function, it will be demonstrated through the ongoing viability of FDD reservoirs five to ten years in the future.

Since volumetric measures cannot be provided, the success of the program must be measured in terms of the accomplishments and the industry evaluations of those accomplishments. Eight highly successful workshops and accompanying publications were completed on eleven FDD horizons. A computer user laboratory was established and continues to be a resource to the industry. Industry relationships with the project participants have shown vast improvements. Industry feedback to the program has been overwhelmingly positive.

Numerous operators and industry people provided positive feedback for the overall program. They indicated that the workshops were extremely valuable and provided important reservoir, geologic, and engineering information. Participants also said they gained a better insight regarding depositional environments and reservoir characteristics which would help them in exploration and development strategies. The regional trend analysis and detailed field study protocol combined with waterflood simulation exercises were directly applicable for most people. Due to the nature of the Oklahoma FDD project, it is recognized as one of the most successful and respected programs to assist operators throughout the entire Mid-Continent region. Nearly everyone wants this program continued or expanded. Because of this, arrangements have been made with the Oklahoma City Geological Society to present "repeat" workshops of some of the workshops, and requests for copies of the play publications continue to be received. Furthermore, the Oklahoma Geological Survey has plans to continue with the "play analysis" format as a permanent component of their overall program. The development of this FDD program and the support of the U.S. Department of Energy have set the stage for a strong technology transfer foundation for Oklahoma's petroleum industry.

VII. REFERENCES

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ATTENDEE EVALUATION SUMMARY REPORT
FDD WORKSHOP: LAYTON & OSAGE-LAYTON PLAY

April 17, 1996 **Oklahoma City, OK**

DEMOGRAPHIC INFORMATION

Type of Company	Small Independent	Major Producer	Service Co.	Govern-ment	Mid/Large Independent	Acad-emia	Con-sultant	Other	# of responses
TOTALS	16	1	1	1	1	0	8	0	28
[redacted]									
Technical Background	Geol/Geoph	Engr	Both	Other					
TOTALS	21	3	0	2					26

How did you learn about this workshop?

- mailing 13
- conversation with OGS staff 2
- attending other workshops 2
- word of mouth 2
- OGS 3
- Tulsa Geol Soc Newsletter 1
- SPE newsletter 1

OVERALL WORKSHOP EVALUATION

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Aver age
Was this workshop useful?	0	0	2	14	13	29	4.38
Was this workshop worth your time and money?	0	1	1	7	19	28	4.57

WORKSHOP AUXILIARY COMPONENTS

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Aver age
Preconference materials	0	0	4	13	11	28	4.25
Registration process	0	0	1	8	20	29	4.66
Presentation facilities	0	0	1	7	21	29	4.69
Supplemental Materials	0	0	3	7	19	29	4.55
Breaks and lunch arrangements	0	0	0	4	25	29	4.86
Overall location	0	0	1	7	21	29	4.69

Please provide any suggestions or comments that you believe would help to improve these workshops.

- more, more, more
- Basically an excellent job...everyone did an excellent job
- Have presenters refer to page #'s and/or figure #'s in their discussions to minimize page flipping
- I would like to attend a seminar on the Bartlesville sand.
- Would like to see a repeat of the Morrow workshop sometime in the future.
- Closer relationship between sample descriptions, core analysis and thin sections with available electric logs.
- Computer demo useful but hard to follow
- Motel/Hotel number on registration form to correlate to map.
- More info on lithology - thin sections, clay minerals, etc.
- Keep up this high quality!
- Great job, keep it up.

- Very well done.

Do you see an opportunity to apply the information and/or technologies discussed in today's workshop? YES: 21 NO: 1

If so, what information and/or technologies?

- We have recompletions in both the True Layton and the Corrage Grove that have been proposed and approved. This information will prove very useful in recompletion choices.
- This type of study emphasizes the work that is yet to be done in order to maximize OK production, both in terms of production enhancement and exploration. You have uncovered a lot of potential areas for further study.
- Geologic info & review of things I have not used lately. Reservoir simulation was interesting and possibly useful.
- The fact that it is not at all unusual for low resistivity changes to be the difference between production and water makes our observations more important and encourages me to map sands for recompletion that at first glance appear wet.
- Being employed by an independent operator, I no longer have the opportunity to increase skills & knowledge by attending in-house schools. This workshop is a fantastic substitute. I predict this idea will be a great help to the independent petroleum operator.
- Reservoir simulation & care that must be given low resistivity reservoirs.
- Regional data as well as specific prospect areas.
- Logs & x-sections for correlation purposes;nomenclature;production analogs;reservoir simulation study;sequence stratigraphy
- In mapping & prospecting
- Investigation of passed-over potential
- Knowledge gained from regional perspectives

PRESENTATION DETAILS	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Aver age
Mankin: Opening Remarks: Technical content	0	0	9	13	9	31	4.00
Mankin: Opening Remarks: Value of the info	0	0	6	16	9	31	4.10
Mankin: Opening Remarks: Applicability to you	0	1	8	11	10	30	4.00
Campbell: Intro to FDD: Technical content	0	0	6	13	12	31	4.19
Campbell: Intro to FDD: Value of the info	1	0	4	12	14	31	4.23
Campbell: Intro to FDD: Applicability to you	0	1	5	12	13	31	4.19
Campbell: Lower Missourian Strat: Technical content	0	0	4	15	12	31	4.26
Campbell: Lower Missourian Strat: Value of the info	0	0	3	15	13	31	4.32
Campbell: Lower Missourian Strat: Applicability to	0	0	6	13	12	31	4.19
Campbell: Regional Overview: Technical content	0	0	2	17	11	30	4.30
Campbell: Regional Overview: Value of the info	0	0	4	12	14	30	4.33
Campbell: Regional Overview: Applicability to you	0	0	4	12	14	30	4.33
Shannon: South Coyle Field: Technical content	0	1	8	14	7	30	3.90
Shannon: South Coyle Field: Value of the info	0	1	10	10	9	30	3.90
Shannon: South Coyle Field: Applicability to you	0	4	8	11	7	30	3.70
Campbell: East Lake Blackwell: Technical content	0	0	6	15	9	30	4.10
Campbell: East Lake Blackwell: Value of the info	0	1	7	10	12	30	4.10
Campbell: East Lake Blackwell: Applicability to you	0	3	6	11	10	30	3.93
Knapp & Yang: Res. Simulation: Technical content	0	1	5	11	13	30	4.20
Knapp & Yang: Res. Simulation: Value of the info	0	4	6	11	9	30	3.83
Knapp & Yang: Res. Simulation: Applicability to you	1	4	9	7	9	30	3.63
Core Exhibits Technical content	0	1	7	11	9	28	4.00
Core Exhibits Value of the info	0	1	7	9	11	28	4.07
Core Exhibits Applicability to you	0	2	7	9	10	28	3.96
Computer Demonstrations Technical content	0	0	6	13	8	27	4.07
Computer Demonstrations Value of the info	0	3	6	11	7	27	3.81
Computer Demonstrations Applicability to you	0	2	7	11	7	27	3.85

FDD WORKSHOP: SKINNER AND PRUE PLAYS

June 19 & 20, 1996
June 26, 1996

Oklahoma City, OK
Bartlesville, OK

DEMOGRAPHIC INFORMATION

Type of Company	Small Independent	Major Producer	Service Co.	Govern-ment	Mid/Large Independent	Acad-emia	Con-sultant	Other	# of responses
TOTALS	47	2	2	0	6	0	19	2	78
June 19	20	0	1	0	3	0	9	0	33
June 20	10	1	0	0	2	0	3	0	16
June 26	17	1	1	0	1	0	7	2	29
Technical Background	Geol/Geoph	Engr	Both	Other					
TOTALS	54	9	5	6					74
June 19	26	1	3	2					32
June 20	11	4	1	0					16
June 26	17	4	1	4					26

How did you learn about this workshop?

	June 19	June 20	June 26	TOTAL
mailing	17	9	15	41
company announcement			1	1
other workshops	4	1	3	8
OGS	3	1	1	5
TGS Newsletter			2	2
Newsletter		1	2	3
OGS Advertisement			1	1
OKC Geol Library	2	1		3
Friends/word of mouth	4	3		7
FDD literature	1		1	2
OGS/OIPA		1		1
Shale Shaker		1		1
Tulsa World News		1		1

OVERALL WORKSHOP EVALUATION

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Aver age
Was this workshop useful?	0	0	7	40	29	76	4.29
June 19	0	0	2	17	13	32	4.34
June 20	0	0	3	7	5	15	4.13
June 26	0	0	2	16	11	29	4.31
Was this workshop worth your time and money?	0	0	5	27	42	74	4.50
June 19	0	0	1	10	21	32	4.63
June 20	0	0	3	7	5	15	4.13
June 26	0	0	1	10	16	27	4.56

WORKSHOP AUXILIARY COMPONENTS

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
Preconference materials	0	1	20	27	26	74	4.05
June 19	0	1	6	11	12	30	4.13
June 20	0	0	6	5	4	15	3.87
June 26	0	0	8	11	10	29	4.07
Registration process	0	0	6	29	41	76	4.46
June 19	0	0	3	11	18	32	4.47
June 20	0	0	1	6	8	15	4.47
June 26	0	0	2	12	15	29	4.45
Presentation facilities	0	0	1	28	47	76	4.61
June 19	0	0	0	13	19	32	4.59
June 20	0	0	0	4	11	15	4.73
June 26	0	0	1	11	17	29	4.55
Supplemental Materials	0	0	5	34	37	76	4.42
June 19	0	0	3	12	17	32	4.44
June 20	0	0	1	7	7	15	4.40
June 26	0	0	1	15	13	29	4.41
Breaks and lunch arrangements	0	0	5	17	53	75	4.64
June 19	0	0	2	5	25	32	4.72
June 20	0	0	0	2	12	14	4.86
June 26	0	0	3	10	16	29	4.45
Overall location	1	0	3	20	50	74	4.59
June 19	1	0	1	7	23	32	4.59
June 20	0	0	0	1	12	13	4.92
June 26	0	0	2	12	15	29	4.45

Please provide any suggestions or comments that you believe would help to improve these workshops.

June 19:

- This is a first class workshop in all respects. Very professional. I'm impressed.
- You must come to Tulsa, half of industry excluded when you don't. All previous presentations (Morrow, etc.) should be done in Tulsa.
- Great workshop & lecture data
- Continue the good work. Geologists need the education & networking.
- A+!
- Show slides of cores or have us look @ photos in book @ 9:10 a.m.: (1) explain main features (2) encourage us to see the features on our own during break (3) rotate core expert between core tables during break to answer questions we may have.
- Waterflood segments too short, hard to understand. Please let us know when Boast 3 is available.
- Best location yet.

June 20:

- Allow more time for engineering discussion.
- Keep lights up a little more (too dark during some of the presentations for note taking.)
- Great place to have these workshops.
- I got a flyer about the workshop but not any registration material. I had to ask around to get the registration form. I missed the earlier workshops for the same reason.
- Limited access of telephone at breaks for the use of attendees. Noticed some staff held the phone for many minutes.
- I feel these workshops are great, I wish our survey (Kansas) would contribute half of what the OGS has been doing!
- Try to present the materials in a manner that can be easily understood by company personnel that may not have a strong geology background, such as workover and completion engineers.
- Leave lights on (dim at least) during slide presentations. It was too dark for me to see to take notes during the first couple of talks.

- Would appreciate including data regarding stimulation procedures, injection rates & volumes

June 26:

- Good workshop.
- Phillips has uncomfortable chairs!
- Excellent overheads - these really help the presentation
- Scales on logs!
- Have producers do these vs. school teachers.
- Since the bulk of the data that is available to an independent geologist is electric logs, it would really be helpful to see what log signatures correspond to the cores. A small display of the electric log showing the cored intervals and a short description of all or just noteworthy lithologies would just be great.
- Maybe supply economic discussion - Feasibility of each study field; or even separate study of mature floods and their economic impact - failure or success although no one would comment on their failures.
- Workshop presentations and cost is excellent. Can't think of any suggestions. Very helpful!
- More information regarding initial treatment of wells.
- Great format. Excellent materials provided for follow-up research.
- Have E-logs laid out along cores.
- Come to Tulsa. I am surprised no one studied the fracture pattern in the field study areas.
- How about Tulsa U or TJC?

Do you see an opportunity to apply the information and/or technologies discussed in today's workshop?

June 19:	YES: 22	NO: 0
June 20:	YES: 10	NO: 1
June 26:	YES: 17	NO: 2

If so, what information and/or technologies?

June 19:

- Fine regional studies.
- I made a list of prospect and further investigation ideas.
- Reservoir simulations
- Secondary Recoveries
- Computer Mapping
- Injection patterns & waterflood evaluation criteria. Regional Skinner correlations will help understanding of local terminology.
- The general approach to sand reservoirs and how to plan secondary recoveries from those reservoirs.
- All of it!
- Software USA

June 20:

- Clearer understanding of regional framework of both reservoir systems.
- Study and development of Skinner wells. Will use study for mapping & sales.
- It always helps seeing field interpretations to help give ideas of how to make environment interpretations.
- There was no new information or technology introduced. Admitted that not all available data was used to make the interpretations.
- Continuation of log curve analysis as exploration tool.
- Field studies, regional overview.
- I will use this information for modeling
- NRIS; exposure to reservoir simulators and mapping software.
- Found out what is really happening (geologically) in my L. Skinner field.

June 26:

- Boast 3 - Excel links
- Regional geology very helpful; interpretation of log characteristics as relating to specific environments.
- Interesting demonstration of Boast
- information of the regional Skinner & Prue in Oklahoma plus examples of existing fields
- computer simulation
- Greater understanding of Fluvial environments will aid our exploration process.
- Uphole potential

- Geological interpretations/evaluations for Analogy. Geographic localvalued if applicable (??)
- All except computer
- Geological mapping & interpretation

PRESENTATION DETAILS	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Aver age
Mankin: Opening Remarks: Technical content	0	3	25	29	19	76	3.84
June 19	0	2	8	16	9	35	3.91
June 20	0	0	6	5	3	14	3.79
June 26	0	1	11	8	7	27	3.78
Mankin: Opening Remarks: Value of the info	0	0	23	34	20	77	3.96
June 19	0	0	9	18	8	35	3.97
June 20	0	0	5	5	5	15	4.00
June 26	0	0	9	11	7	27	3.93
Mankin: Opening Remarks: Applicability to you	1	1	24	30	19	75	3.87
June 19	1	1	7	17	9	35	3.91
June 20	0	0	7	3	4	14	3.79
June 26	0	0	10	10	6	26	3.85
Andrews: Intro to FDD: Technical content	1	1	12	40	30	84	4.15
June 19	0	0	5	21	13	39	4.21
June 20	1	0	3	6	5	15	3.93
June 26	0	1	4	13	12	30	4.20
Andrews: Intro to FDD: Value of the info	1	1	18	36	27	83	4.11
June 19	0	0	7	18	13	38	4.16
June 20	1	0	4	6	4	15	3.80
June 26	0	1	4	13	12	30	4.20
Andrews: Intro to FDD: Applicability to you	1	2	17	37	26	83	4.02
June 19	0	0	7	19	12	38	4.13
June 20	1	1	3	6	4	15	3.73
June 26	0	1	7	12	10	30	4.03
Andrews: Skinner/Senora Regional: Technical content	0	0	6	47	35	88	4.33
June19	0	0	2	21	16	39	4.36
June 20	0	0	2	10	4	16	4.13
June 26	0	0	2	16	15	33	4.39
Andrews: Skinner/Senora Regional: Value of the info	0	0	9	44	35	88	4.30
June 19	0	0	3	19	17	39	4.36
June 20	0	0	3	9	4	16	4.06
June 26	0	0	3	16	14	33	4.33
Andrews: Skinner/Senora Regional: Applicability to	0	2	13	46	27	88	4.11
June 19	0	1	5	20	13	39	4.15
June 20	0	1	4	8	3	16	3.81
June 26	0	0	4	18	11	33	4.21
Rottmann: Guthrie SW Technical content	0	4	22	40	19	85	3.87
June 19	0	2	6	20	10	38	4.00
June 20	0	1	3	6	4	14	3.93
June 26	0	1	13	14	5	33	3.70
Rottmann: Guthrie SW Value of the info	0	3	17	47	18	85	3.94
June 19	0	0	5	22	11	38	4.16
June 20	0	1	4	6	3	14	3.79
June 26	0	2	8	19	4	33	3.76
Rottmann: Guthrie SW Applicability to you	0	3	28	37	17	85	3.80
June 19	0	0	11	17	10	38	3.97
June 20	0	2	5	4	3	14	3.57
June 26	0	1	12	16	4	33	3.70
Andrews: Salt Fork North Technical content	0	1	12	53	19	85	4.06
June 19	0	0	5	25	8	38	4.08

June 20	0	1	2	8	3	14	3.93
June 26	0	0	5	20	8	33	4.09
Andrews: Salt Fork North Value of the info	0	3	12	45	25	85	4.08
June 19	0	0	5	22	11	38	4.16
June 20	0	1	2	8	3	14	3.93
June 26	0	2	5	15	11	33	4.06
Andrews: Salt Fork North Applicability to you	0	5	16	39	25	85	3.99
June 19	0	0	6	21	11	38	4.13
June 20	0	2	4	5	3	14	3.64
June 26	0	3	6	13	11	33	3.97
Knapp & Bhatti: Salt Fork North: Technical content	3	4	23	36	20	86	3.77
June 19	2	3	13	14	7	39	3.54
June 20	1	0	1	9	4	15	4.00
June 26	0	1	9	13	9	32	3.94
Knapp & Bhatti: Salt Fork North: Value of the info	2	5	35	31	13	86	3.56
June 19	1	4	15	13	6	39	3.49
June 20	1	0	5	6	3	15	3.67
June 26	0	1	15	12	4	32	3.59
Knapp & Bhatti: Salt Fork North: Applicability to you	1	8	37	26	14	86	3.51
June 19	0	4	19	10	6	39	3.46
June 20	1	2	5	4	3	15	3.40
June 26	0	2	13	12	5	32	3.63
Rottmann: Perry SE Technical content	0	1	16	42	26	85	4.09
June 19	0	0	6	18	14	38	4.21
June 20	0	0	4	7	4	15	4.00
June 26	0	1	6	17	8	32	4.00
Rottmann: Perry SE Value of the info	0	3	16	39	27	85	4.06
June 19	0	1	4	18	15	38	4.24
June 20	0	0	5	6	4	15	3.93
June 26	0	2	7	15	8	32	3.91
Rottmann: Perry SE Applicability to you	0	2	18	40	24	84	4.02
June 19	0	1	6	18	13	38	4.13
June 20	0	0	5	7	3	15	3.87
June 26	0	1	7	15	8	31	3.97
Andrews: Prue/Calvin Regional Technical content	0	1	11	42	29	83	4.19
June 19	0	1	5	17	13	36	4.17
June 20	0	0	3	8	4	15	4.07
June 26	0	0	3	17	12	32	4.28
Andrews: Prue/Calvin Regional Value of the info	0	3	12	34	34	83	4.19
June 19	0	2	5	14	15	36	4.17
June 20	0	0	3	7	5	15	4.13
June 26	0	1	4	13	14	32	4.25
Andrews: Prue/Calvin Regional Applicability to you	1	3	15	35	28	82	4.05
June 19	0	3	7	15	11	36	3.94
June 20	0	0	4	6	4	14	4.00
June 26	1	0	4	14	13	32	4.19
Andrews: Long Branch Technical content	1	1	10	38	32	82	4.21
June 19	0	1	3	17	14	35	4.26
June 20	1	0	2	7	5	15	4.00
June 26	0	0	5	14	13	32	4.25
Andrews: Long Branch Value of the info	1	1	11	37	32	82	4.20
June 19	0	1	3	17	14	35	4.26
June 20	1	0	1	8	5	15	4.07
June 26	0	0	7	12	13	32	4.19
Andrews: Long Branch Applicability to you	3	0	16	34	28	81	4.04
June 19	1	0	7	15	12	35	4.06

June 20	1	0	2	7	4	14	3.93
June 26	1	0	7	12	12	32	4.06
Knapp & Yang: Long Branch Technical content	0	4	17	30	17	68	3.88
June 19	0	2	7	14	6	29	3.83
June 20	0	0	5	2	5	12	4.00
June 26	0	2	5	14	6	27	3.89
Knapp & Yang: Long Branch Value of the info	0	4	25	25	14	68	3.72
June 19	0	1	10	12	6	29	3.79
June 20	0	0	5	4	3	12	3.83
June 26	0	3	10	9	5	27	3.59
Knapp & Yang: Long Branch Applicability to you	4	7	21	23	13	68	3.50
June 19	2	1	11	10	5	29	3.52
June 20	0	1	4	4	3	12	3.75
June 26	2	5	6	9	5	27	3.37
Core Exhibits Technical content	0	1	7	32	30	70	4.30
June 19	0	0	3	16	11	30	4.27
June 20	0	0	1	3	7	11	4.55
June 26	0	1	3	13	12	29	4.24
Core Exhibits Value of the info	0	2	6	37	25	70	4.21
June 19	0	0	4	17	9	30	4.17
June 20	0	0	1	3	7	11	4.55
June 26	0	2	1	17	9	29	4.14
Core Exhibits Applicability to you	1	0	9	33	26	69	4.20
June 19	0	0	6	15	9	30	4.10
June 20	0	0	1	3	6	10	4.50
June 26	1	0	2	15	11	29	4.21
Computer Demonstrations Technical content	0	1	11	23	16	51	4.06
June 19	0	1	5	8	7	21	4.00
June 20	0	0	1	2	4	7	4.43
June 26	0	0	5	13	5	23	4.00
Computer Demonstrations Value of the info	1	1	10	26	13	51	3.96
June 19	0	0	6	10	5	21	3.95
June 20	0	0	1	3	3	7	4.43
June 26	1	1	3	13	5	23	3.87
Computer Demonstrations Applicability to you	2	2	9	24	14	51	3.90
June 19	0	1	5	9	6	21	3.95
June 20	0	0	2	2	3	7	4.14
June 26	2	1	2	13	5	23	3.78

FDD WORKSHOP: CLEVELAND AND PERU PLAYS

October 17, 1996 **Bartlesville, OK**

DEMOGRAPHIC INFORMATION

Type of Company	Small Independent	Major Producer	Service Co.	Govern-ment	Mid/Large Independent	Academ ia	Con-sultant	Other	# of responses
TOTALS	13	0	0	1	1	0	2	2	19
Technical Background	Geol/Geoph	Engr	Both	Other					
TOTALS	15	1	0	3					19

How did you learn about this workshop?

	TOTAL
mailing	8
other workshops	3
OGS	2
Friends/word of mouth	3

OVERALL WORKSHOP EVALUATION

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Aver age
Was this workshop useful?	0	2	4	8	5	19	3.84
Was this workshop worth your time and money?	0	2	2	6	9	19	4.16

WORKSHOP AUXILIARY COMPONENTS

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Aver age
Preconference materials	0	2	6	6	4	18	3.67
Registration process	0	0	4	1	14	19	4.53
Presentation facilities	0	0	0	5	14	19	4.74
Supplemental Materials	0	0	4	10	5	19	4.05
Breaks and lunch arrangements	0	0	3	3	13	19	4.53
Overall location	0	0	2	7	10	19	4.42

Please provide any suggestions or comments that you believe would help to improve these workshops.

- A great job as usual.
- I have rated all presentations as average. All presenters did an excellent job but presented very little that could be considered new. I found the Pleasant Mound Reservoir simulation to be most interesting from a content point of view.
- Field studies of more general interest, even though e. logs, cores, etc. may not be available. Computer simulations are not helpful to average attendee.
- All of the presenters did a really good job, however I was left with the feeling that there is not a lot of future to these two reservoirs. Neither of the field studies were very economic, or was that the point?
- The seminar proved valuable by showing a zone which we always wondered about but never had time to map.
- Why Bartlesville location? It would seem that more might avail themselves to the workshop if in OKC & Tulsa primarily....I have been to several workshops, but never in Tulsa...Are there facilities here? Also, I felt the Peru portion was practically a waste of time due to the lack of economic significance of this reservoir. Based on the presentation, I don't know many operators that would re-complete this zone, much less drill for it.
- Could have found some better Peru wells in Osage - Even made workovers behind pipe not feasible for Peru. Should have spent one day per zone study - Some old geologists never change.
- The "plays"presented were not commercially feasible.

- This was the poorest of the series. Previous workshops were better prepared & discussed in more detail. Overall the series has been great. Please keep the program expanding even into other geologic areas.
- Provide core analysis of cores on display and full log suite.
- I would like to see upcoming workshops held in Bartlesville again.
- Great facility - good for folks operating in central & NE Oklahoma.
- Wish all day on Cleveland!
- Core was very good - Could have used core analysis data & correlative core/log relationship quantification. Discussion of secondary projects needs more than 1 project, and info on what works, what are problems to be aware of, etc.

Do you see an opportunity to apply the information and/or technologies discussed in today's workshop? YES: 17 NO: 0

If so, what information and/or technologies?

- Log analysis by Bruce Carpenter contained a great deal of universal information that I have found useful.
- This workshop provided me with review of Cleveland and Peru sand information that I need for my present job.
- Waterflood technology
- Overview of formations studied
- Bruce Carpenter's talk was very helpful in evaluating logs.
- The history matching at Pleasant Mound is deemed worthy of further investigation. Excellent program!!
- Extent of Cleveland production.
- Infield drilling on Cleveland sand leases - most studies say won't flood? I believe it will & has in some compartmental instances. As usual you guys & gals do an excellent job!
- Fluvial vs. marine
- Geological info will help in future prospecting.
- Engineering reservoir simulations give insight into secondary recovery operations.
- Location of Clev. fields w/in whole depositional setting...as explanation for some probs. w/ low Rt, grain size (pore size) vs. perm. distribution -- & need for core!

PRESENTATION DETAILS	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
1. Mankin: Opening Remarks	0	0	5	7	6	18	4.06
2. Jock Campbell: Introduction to FDD Concepts	0	0	6	9	3	18	3.83
3. Jock Campbell: Cleveland Regional Overview	0	0	5	11	2	18	3.83
4. Kurt Rottmann: Pleasant Mound Field Study	0	1	6	9	2	18	3.67
5. Knapp & Yang: Pleasant Mound Reservoir Simulation	0	5	4	6	3	18	3.39
6. Robert Northcutt: Peru Regional Overview	1	4	7	4	1	17	3.11
7. Robert Northcutt: Hogshooter Field Study	1	4	5	6	0	16	3.11
8. Bruce Carpenter: Hogshooter Log Analysis	0	1	3	10	2	16	3.81
9. Core Exhibits	0	0	3	11	3	17	4.00
10. Computer Demonstrations	0	0	3	10	3	16	4.00

FDD WORKSHOP: RED FORK PLAY

March 5, 1997 — Norman, OK
March 12, 1997 — Bartlesville, OK

DEMOGRAPHIC INFORMATION

Type of Company	Small Independent	Major Producer	Service Co.	Govern-ment	Mid/Large Independent	Acad-emia	Con-sultant	Other	# of responses
TOTALS	52	5	5	2	9	0	10	0	83
March 5	24	3	3	1	6	0	4	0	41
March 12	28	2	2	1	3	0	6	0	42
Technical Background	Geol/Geoph	Engr	Both	Other					
TOTALS	56	12	5	9					82
March 5	34	4	0	3					41
March 12	22	8	5	6					41

How did you learn about this workshop?

	March 5	March 12	TOTAL
mailing	30	20	50
company announcement	1	1	2
other workshops	3	2	5
OGS	2	6	8
OKC/Tulsa Geol Soc.	1	3	4
Friends/word of mouth	2	4	6
Newspaper		5	5
Web page		1	1

OVERALL WORKSHOP EVALUATION

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Aver age
Was this workshop useful?	0	0	2	44	36	82	4.41
March 5	0	0	1	23	17	41	4.39
March 12	0	0	1	21	19	41	4.44
Was this workshop worth your time and money?	0	0	1	36	45	82	4.54
March 5	0	0	1	21	19	41	4.44
March 12	0	0	0	15	26	41	4.63

WORKSHOP AUXILIARY COMPONENTS

	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Aver age
Preconference materials	0	1	11	40	27	79	4.18
March 5	0	1	5	20	14	40	4.18
March 12	0	0	6	20	13	39	4.18
Registration process	0	0	7	22	54	83	4.57
March 5	0	0	5	11	25	41	4.49
March 12	0	0	2	11	29	42	4.64
Presentation facilities	0	0	0	17	66	83	4.80
March 5	0	0	0	5	36	41	4.88
March 12	0	0	0	12	30	42	4.71
Supplemental Materials	0	0	5	26	52	83	4.57
March 5	0	0	4	11	26	41	4.54
March 12	0	0	1	15	26	42	4.60
Breaks and lunch arrangements	0	1	3	25	53	82	4.59
March 5	0	0	2	9	30	41	4.68
March 12	0	1	1	16	23	41	4.49
Overall location	0	2	6	34	40	82	4.37
March 5	0	1	2	11	26	40	4.55
March 12	0	1	4	23	14	42	4.19

Please provide any suggestions or comments that you believe would help to improve these workshops
March 5:

- Might be good to have more presentations from Redfork operators - I recall at Morrow workshop you had a couple of private companies give talks on their fields/3D etc. - which was excellent.
- Better directions/location within postal service center (i.e., building at far end, etc.)
- Would like to have seen one field study where the Red Fork was split into upper & lower members.
- Meeting facilities were good.
- OK is primarily a gas producer. Have similar programs on Red Fork gas reservoirs.
- As a small independent operator, I need technical support which is not available except to major companies.
- Continue program.
- Keep up the good work!
- Can you do additional field studies, such as Red Fork Play II?
- Need to do more for the low resistivity Redfork sand with high porosity, in say Lincoln Co.
- Too much time spent on production models. Reviewing one case and summary of variables is all that is needed because it is just a model! Shows quickly how well model matches data.
- Would like to see more workshops.
- Place logs along side of core samples.
- The Red Fork play is the best yet: Excellent slides, excellent food, excellent speakers.
- Keep up the good work.
- Add wireline log/core.
- The organization - management - & conduct of the workshop was outstanding.
- This entire series of FDD sessions has been superlative - keep them coming!
- Expand into gas producing areas. I would be very interested in an Ordovician Clastics study.
- Better directions to room location.
- Someday repeat the early workshops - Booch, etc. Many people missed the opportunity!
- Need a sign outside!
- More of them - other sand dep. environments & carbonates too! Also, a workshop on the application of Geology in Secondary (recovery) may help lots of operators who are interested in that type of development. Probably should include work in increased density drilling of "deeper"reservoirs and the compartmentalization of them - lots of potential here in Oklahoma.
- All of you have done incredible jobs in gathering and presenting data. I am amazed at how much work you have done.
- Field Studies? Any work on grain-size/perm. relationships & transition zones?

March 12:

- Keep using this facility.
- Excellent! Speaker should repeat aloud questions from the floor.
- From Tulsa - can't really complain, a very nice facility & setup. The price is obviously right too!
- Lobby displays needed more room.
- More field studies...the reservoir simulation wasn't of interest to me: too far from my geologic interest.
- The types of computer models are nebulous at best. I much preferred the waterflood presentation on the Morrow. (Actual case history.)
- Enjoyed photos at beginning, especially the surface outcroppings. I did purchase some OGS publications onsite.
- Given costs etc., Bartlesville is fine.
- More plays significant in Oklahoma, or potential plays.
- Workshop on internet & NRIS resources.
- Would like workshop on Coal seam gas in Oklahoma. Other exploration methods, seismic, areomag, gravity, 3D seismic. Limestone reservoirs, deep Arbuckle, and other zones.
- More workshops on geological techniques and concepts. More workshops on other reservoirs and depositional environments.
- Excellent information, well compiled and presented at a most reasonable fee. Marvelous facility!
- I hate Phillips chairs tho the visibility in the room is excellent.
- Have them more often.
- Ask Amoco Research to cooperate!
- Rick Andrews' presentations were excellent.

Do you see an opportunity to apply the information and/or technologies discussed in today's workshop? March 5: YES: 33 NO: 0

March 12: YES: 36 NO: 0

If so, what information and/or technologies?

March 5:

- % recovery of OOIP with waterflood is striking.
- mapping facies distributions.
- Fluvial vs. Marine deposits.
- Use of API oil gravity to help identify different prod. facies
- Improve knowledge for exploration and future operations.
- Case/field studies for lease evaluation & "protection"
- Great info about application of waterflooding
- Locations of Red Fork sands and how they were developed
- Detailed field studies
- Water flood applications
- Better evaluation of reservoir geometry from aerial photo overview and field studies. Great job by Rick Andrews!
- Adds to my overall regional understanding of the Red Fork plays. How about a follow up workshop on deeper Anadarko Red Fork "tite"gas sands & fields.
- Gravity and facies analysis using it.
- The graphic materials give ideas and aid in recognizing the different depositional features, especially in conjunction with one another.
- Geologic framework for future prospects. Background info regarding reserves & anticipated secondary recovery.
- The study of fluvial dominated systems has changed my outlook on mapping the Cherokee - Made me money.
- We are presently putting in 2 Red Fork waterfloods in Grant & Alfalfa Co. Wish it had been 18 months earlier.
- Reconstructing depositional environments. Redevelopment of older fields. Playing off key wells to find new fields.
- This presentation provides me the incentive to revisit many of my Red Fork plays. By using the more subtle log variations, I should be able to extract more prospects.
- Have some basis to contour point bars with little (no) control.
- Field studies show potential for discoveries of additional hydrocarbon reservoirs.
- Reservoir compartmentalization effects on waterflooding
- Evaluation of reservoirs for secondary. Application of depositional environment to determination of infill/development loc's.

March 12:

- E log signatures. Overall maps.
- Transverse vs. lateral permeability for additional drilling locations.
- Reservoir identification through logs
- Facies analyses
- All of it.
- The general interpretation & specific correlations.
- Geographic areas of Red Fork plays.
- Mainly exploration and water flood techniques.
- Red Fork - facies variations in the context of exploration and exploitation.
- Boast 3. Geological concepts.
- Cherokee sd. devel. in N. Okla.
- Environmental interpretation from E-log signatures.
- Identifying what type reservoir that we produce in.
- Secondary potential. General depositional info.
- Review logs in areas working.
- Strong background for consulting/prospect generation.
- Use of facies patterns in mapping & interpretation.

PRESENTATION DETAILS	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
1. Mankin: Opening Remarks:	0	0	11	36	25	72	4.19
March 5	0	0	6	14	13	33	4.21
March 12	0	0	5	22	12	39	4.18
2. Andrews: Intro to FDD:	0	0	4	31	38	73	4.47
March 5	0	0	3	13	17	33	4.42
March 12	0	0	1	18	21	40	4.50
3.Andrews: Red Fork stratigraphy/regional	0	0	1	30	43	74	4.57
March 5	0	0	1	13	20	34	4.56
March 12	0	0	0	17	23	40	4.58
4. Andrews: N. Carmen Field Study	0	0	5	28	39	72	4.47
March 5	0	0	1	14	19	34	4.53
March 12	0	0	4	14	20	38	4.42
5. Knapp & Yang: N. Carmen waterflood model:	1	5	15	26	23	70	3.93
March 5	0	1	8	11	14	34	4.12
March 12	1	4	7	15	9	36	3.75
6. Rottmann: Otoe City S. Field Study	0	0	15	36	22	73	4.10
March 5	0	0	7	16	11	34	4.12
March 12	0	0	8	20	11	39	4.08
7. Andrews: Long Branch	0	0	4	32	37	73	4.45
March 5	0	0	0	14	20	34	4.59
March 12	0	0	4	18	17	39	4.33
8. Core Exhibits	0	0	6	30	31	67	4.37
March 5	0	0	3	9	20	32	4.53
March 12	0	0	3	21	11	35	4.23
9. Computer Demonstrations	0	2	13	25	19	59	4.03
March 5	0	0	6	9	13	28	4.25
March 12	0	2	7	16	6	31	3.84

Footnotes based on comments written on the back page (by section number):

March 5:

1. OK
2. Aerial photos - excellent
   We all appreciate this segment & do not tire of it as perhaps you think.
   Good
3. Very good - Puts all else into perspective
4. Mapping of facies is good - Should describe characteristics of each zone separately, two types of "flow units". What are wells in "trend" to east/west?
5. Would be of interest to see economics.
   Need to work more closely with geologists & operators -- Also keep in mind dual perm of reservoir!
6. Facies mapping would be good - Any fracturing present? What was ultimate primary vs. secondary?
7. Nice study - Be careful w/ flood pettern! Enjoyed work on separate facies.
8. Great - Adjoining notes are helpful. This info is rare. Thanks.
9. Good - first exposure of many participants to availability and scope of information.

March 12:

1. Nice sum. of program's past & possible future.
2. Excellent photos
3. Exhibit "plates" will be very useful (no matter what depo environ interpretation one subscribes to!)
   Good discussion on controversies
4. Appreciate information on production response to waterflood
5. Thanks for metrics of secondary production estimated from 1997-2001.
   Torpedoed by bad electronics - normally very good presentations.
6. Core from the main field study area would have been nice for interpretation.
8. Good!
   The vote was an interesting idea to get people to really look at core.
9. Map handouts are great to generate interest in what the computer system can do.

FDD WORKSHOP: TONKAWA PLAY

July 9, 1997 — Norman, OK

DEMOGRAPHIC INFORMATION

Type of Company	Small Independent	Major Producer	Service Co.	Govern-ment	Mid/Large Independent	Acad-emia	Con-sultant	Other	# of responses
TOTALS	26	0	0	1	5	0	5	1	38
Technical Background	Geol/Geoph	Engr	Both	Other					
TOTALS	28	7	0	3					38

How did you learn about this workshop?

	TOTAL
mailing	21
other workshops	6
OGS	5
OKC Geol Library	2
Friends/word of mouth	4
Newspaper	1

OVERALL WORKSHOP EVALUATION	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Aver age
Was this workshop useful?	0	1	5	24	9	39	4.05
Was this workshop worth your time and money?	0	1	3	19	16	39	4.28

WORKSHOP AUXILIARY COMPONENTS	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Aver age
Preconference materials	0	0	9	18	11	38	4.05
Registration process	1	0	1	11	26	39	4.56
Presentation facilities	1	0	0	8	30	39	4.69
Supplemental Materials	0	0	3	19	17	39	4.36
Breaks and lunch arrangements	1	0	1	7	29	38	4.66
Overall location	1	1	3	9	25	39	4.44

Please provide any suggestions or comments that you believe would help to improve these workshops

- Try to extend this play into NE Texas Panhandle of Lipscomb & Ochiltree Counties
- Slides were great this time & tied with book. Can't really make any improvement suggestions. Keep up the good work.
- Good Job!
- More speakers on the correlation of depositional environment with log correlation.
- More field studies.
- Well economics. Tonkawa Play economics overall.
- 1) Analysis of water samples, i.e. RW's; 2) sem- x-ray analysis, i.e. clay contents; 3) any unusual log evaluations and/or what is best logging suite; 4) responses of reservoirs to stimulations (any damage problems?).
- More attention to slide quality. Overheads are hard to read. On technical material, try to pick strat. markers below the Tonkawa to use as datum, use shale markers not the top of the sand or limestone. Show porosity curves as well as induction curves.
- Obtain more data from operators, i.e. water production data, corrosion? gas quality? Also, field check these studies - view production equipment, disposal wells, casing problems, etc.
- This was one of the best workshops I have been to.
- Provide more (longer) breaks to allow people to go through displays and information.

- Discussion of problems common to Tonkawa production in Northwest Oklahoma gas play, e.g. low resistivity production and causes.
- 1) Please include slide show of the core so that we can at the breaks view the salient points. 2) Use this workshop to add facts in future Geology Notes or other publications: Example thin sections of key lithologies or core.
- I would have liked more information on the cores. What in the cores supports your interpretation of the depositional environment? How do the marine bar cores differ from the deltaic?.
- I appreciate the "down-to-earth"approach which makes workshops helpful to my engineering discipline and operations, not just academic geology.

Do you see an opportunity to apply the information and/or technologies discussed in today's workshop? YES: 35 NO: 0

If so, what information and/or technologies?

- In everyday drilling & completion activities in the Tonkawa formation.
- Currently working areas to the west of study.
- Suggestions by speaker as to how to map reservoir sands (i.e. using pessimistic cut-off for net picks) could be helpful in determining compartmentalization within reservoir!
- Better understanding of Tonkawa trend. Useful in further exploration.
- Log analysis correlated w/ production.
- Techniques for estimating depositional environment from mechanical log analysis.
- Interpretation of reservoir character as related to water flood potential.
- Depositional environment determinations
- The correct stratigraphy in sorting out true Tonkawa production. Facies analysis and core descriptions in lobby. Sand body orientations.
- Material presented by Kurt Rottmann.
- Will use regional info to help focus my efforts for detail work.
- Tonkawa production.
- FMI logs.
- Continuing plays into the basin and further TX Panhandle areas.
- General idea of environment of deposition
- Infill & offset potential in existing field based on facies trends.
- My company has 2 gas storage projects in the Tonkawa in N. OK for which the basic geology was very fundamental for understanding of additional development w/ multiple lenses, etc..

PRESENTATION DETAILS	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Aver age
1. Mankin: Opening Remarks:	0	0	8	17	9	34	4.03
2. Campbell: Intro to FDD:	0	1	9	18	6	34	3.85
3. Campbell: Tonkawa FDD regional overview:	0	1	12	14	7	34	3.79
4. Rottmann: Blackwell Field Study	0	0	1	19	14	34	4.38
5. Knapp, Samad & Xie: Blackwell Simulation	0	3	14	14	3	34	3.50
6. Hinshaw: Tonkawa Anadarko Regional Overview	0	1	7	16	10	34	4.03
7. Rottmann: Waynoka NE Field Study	0	0	1	18	13	32	4.38
8. Core Exhibits	0	0	6	19	9	34	4.09
9. Computer Demonstrations	0	1	10	15	4	30	3.73

Footnotes based on comments written on the back page (by section number):

1. Some colors don't show up well on overheads.

FDD WORKSHOP: BARTLESVILLE PLAY

October 29, 1997 — **Tulsa, OK**
October 30, 1997 — **Bartlesville, OK**
November 12, 1997 — **Norman, OK**

DEMOGRAPHIC INFORMATION

Type of Company	Small Independent	Major Producer	Service Co.	Govern-ment	Mid/Large Independent	Acad-emia	Con-sultant	Other	# of responses
TOTALS	46	0	1	5	5	1	10	3	71
October 29	22	0	0	5	2	0	5	0	34
October 30	7	0	0	0	0	0	3	0	10
November 12	17	0	1	0	3	1	2	3	27
Technical Background	Geol/Geoph	Engr	Both	Other					
TOTALS	47	12	6	7					72
October 29	20	4	4	6					34
October 30	7	2	0	1					10
November 12	20	6	2	0					28

How did you learn about this workshop?

	October 29	October 30	November 12	TOTAL
mailing	26	6	13	45
other workshops	6	3	6	15
OGS	3	0	5	8
TGS	3	0	0	3
OKC Geol Library	0	0	1	1
Friends/word of mouth	1	1	2	4
Newspaper	0	1	0	1

OVERALL WORKSHOP EVALUATION	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
Was this workshop useful?	0	0	7	38	25	70	4.26
October 29	0	0	4	18	10	32	4.19
October 30	0	0	1	3	6	10	4.50
November 12	0	0	2	17	9	28	4.25
Was this workshop worth your time and money?	0	0	5	31	35	71	4.42
October 29	0	0	4	16	13	33	4.27
October 30	0	0	0	2	8	10	4.80
November 12	0	0	1	13	14	28	4.46

WORKSHOP AUXILIARY COMPONENTS	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
Preconference materials	0	0	12	30	27	69	4.22
October 29	0	0	9	12	11	32	4.06
October 30	0	0	1	5	3	9	4.22
November 12	0	0	2	13	13	28	4.39
Registration process	0	0	2	23	46	71	4.62
October 29	0	0	2	11	20	33	4.55
October 30	0	0	0	2	8	10	4.80
November 12	0	0	0	10	18	28	4.64
Presentation facilities	0	0	3	19	49	71	4.65
October 29	0	0	3	14	16	33	4.39
October 30	0	0	0	0	10	10	5.00
November 12	0	0	0	5	23	28	4.82

Supplemental Materials	0	0	4	33	32	69	4.41
October 29	0	0	3	20	8	31	4.16
October 30	0	0	0	4	6	10	4.60
November 12	0	0	1	9	18	28	4.61
Breaks and lunch arrangements	2	9	9	14	36	70	4.04
October 29	2	9	8	6	7	32	3.22
October 30	0	0	1	1	8	10	4.70
November 12	0	0	0	7	21	28	4.75
Overall location	0	2	12	20	37	71	4.30
October 29	0	2	10	13	8	33	3.82
October 30	0	0	0	0	10	10	5.00
November 12	0	0	2	7	19	28	4.61

Please provide any suggestions or comments that you believe would help to improve these workshops

October 29:

- Lunch outdoors on a cool windy day...otherwise "4".
- **Please do Hunton, Viola, Simpson, & Arbuckle workshops**.
- Need Gamma Ray of outcrop to compare to GR of core. Purchase a hand-held Gamma Ray Tool to measure the weathered response of the rocks that crop out. In this manner your photos of the outcrops are meaningful to us who look at your cores and logs. Keep up the excellent core photos in the guidebook. I would send out these core photos with promotion on the school or at least to those who are registered. Expand core photos to all major lith/environments. In this manner an operator will buy your guidebook for the core that is in his garage.
- When you have a seminar this late in the year, don't arrange to have lunch outdoors.
- Get preconference materials out earlier to help with planning. Move along more quickly - leaving more time for questions/discussion. Work the operators for the data ...too much is never reported via state records. Roy Knapp (& others) - include some economics in these studies....Don't worry if your #'s are inexact, but do make some financial evaluation!
- Use more non-technical language.
- Rather than reduce the number of projects in the future (due to loss of funding) I would reduce the amenities (break food & beverages).
- **Do a workshop on strat-trap reservoirs.**
- Good food, poor conditions for lunch. **How about other seminars on 1. NRIS, 2. Seismic for really small operators, 3. Mississipian, Devonian, (older formations), 4. computer software applications for small operators, i.e. reservoir simulator usage, contour & isopach mapping.**
- Great job! **Can we something on the Arbuckle, or deeper potential below old eastern Oklahoma oil fields?**
- **More data on understanding seismic data. Seminar on Misener/Simpson Series etc.**
- Don't have lunch outside. I was disappointed that there was not much concentration on a wide variety of B-ville producers in the heart of the Bartlesville through big producing areas such as Creek Co.
- Excellent - good planning. Possibly different type lunch, but not complaining. Appreciate these workshops.
- Almost perfect! Don't change the format.
- Very good meeting - thanks so much!
- **I would like to see similar workshop like this for the Mississippi Lm in c. Oklahoma.**

October 30:

- Don't Stop.
- Your continuation, even at more conservative pace, would be helpful - **Suggested topics of Mw/Spr, Deep Red Fork, & Arkoma basins would be helpful**.
- Continue the "excellent" work.
- Closer interfingering of publication figures with slides presented with lectures.
- **Would really like to see a regional workshop on Mississippian Rocks for central and eastern Oklahoma.**

November 12:

- Case studies of completed, successful, secondary recovery projects.
- This is really hard to improve and I'm serious. Keep up the good work. As a taxpayer - this is money well spent.
- Maybe more emphasis on larger fields and/or infill drilling opportunities.
- **Onward to Carbonates!**
- **Chester limestone in northwest Oklahoma** - porosity types/systems - stratigraphic complexities.
- Field Trips. Proper completion techniques for a given reservoir.
- Do a field trip in conjunction with the workshop.
- Very impressive, "user friendly"environment for conferences; presenters were well prepared - good job!

Do you see an opportunity to apply the information and/or technologies discussed in today's workshop?

October 29:	YES: 29	NO: 1
October 30:	YES: 9	NO: 0
November 12:	YES: 20	NO: 0

If so, what information and/or technologies?

October 29:

- Analogous comparisons...reinforcement of general information from previous FDD's too.
- Log correlations & environments in the type log & x-section displays. Each time I attend one of these I hear something a little differently and thus re-think the previous schools.
- This was helpful in using facies to predict where to drill the next well. The facies mapping can be applied to other similar formations.
- Waterflooding in small fields - but need some economic evaluation of various case studies...Possibility of using 2-D seismic for stratigraphic boundary interpretation.
- Log signature interpretation in determination of facies within an environment of deposition, mapping style, etc.
- Environmental facies recognition.
- Regional facies interpretation into a depositional model.
- Utilize data that is available to review old areas.
- Mapping and prospecting for Bartlesville Sand.
- Ideas about how to prospect for Bartlesville sand.
- Point bar deliveation in more detail.
- Be alert to low rt values in prod. Bartlesville sands. Use of log characteristics to define depositional environments.
- More familiar w/fluvial log signatures
- Assist in regulating lease provisions on drainage, diligent development.
- General interpretation of localized depositions.

October 30:

- Analysis of individual sands on log to better define what is happening in the B'ville and to refine beyond isopach/structural trends.
- Will request one operator to assign shut-in leases.
- All.
- Exploration methods.
- Should be helpful in tracking channel sands of all formations, not limited to Bartlesville.
- 1.) The use of well log character in determining depositional environment. 2.) the regional Bartlesville depositional map and direction of deposition.
- Starting new water floods.

November 12:

- Differentiation of sand developments within the usual depositional environment.
- Information from production that confirms barriers mapped and interpreted on environments from log data that encourages the use of such interpretations to design flood programs.
- Seismic stratigraphy application to sand prediction.
- Potential waterflood project.
- Facies signatures on electric logs.
- Geo information systems - water quality, shallow aquifers - enjoyed visit w/Mary Banken (GIS).

PRESENTATION DETAILS	1 (Poor)	2	3 (Avg.)	4	5 (Great)	# of responses	Average
1. Mankin: Opening Remarks:	0	0	10	33	23	66	4.20
October 29	0	0	6	12	14	32	4.25
October 30	0	0	1	6	2	9	4.11
November 12	0	0	3	15	7	25	4.16
2. Northcutt: Intro to FDD:	0	2	17	29	18	66	3.95
October 29	0	1	9	15	7	32	3.88
October 30	0	0	2	3	4	9	4.22
November 12	0	1	6	11	7	25	3.96
3. Northcutt: Bartlesville regional overview:	1	1	15	33	16	66	3.94
October 29	1	0	10	15	6	32	3.78
October 30	0	0	1	4	4	9	4.33
November 12	0	1	4	14	6	25	4.00
4. Andrews: Paradise Field Study	0	0	5	30	31	66	4.39
October 29	0	0	4	14	14	32	4.31
October 30	0	0	0	2	7	9	4.78
November 12	0	0	1	14	10	25	4.36
5. Knapp et al.: Paradise Waterflood Model:	0	3	20	30	11	64	3.77
October 29	0	2	12	14	3	31	3.58
October 30	0	0	2	3	3	8	4.13
November 12	0	1	6	13	5	25	3.88
6. Andrews: Russell NW Field Study	0	1	8	32	24	65	4.22
October 29	0	1	6	14	10	31	4.06
October 30	0	0	1	3	5	9	4.44
November 12	0	0	1	15	9	25	4.32
7. Riepl: Seismic Stratigraphy	0	4	20	28	14	66	3.79
October 29	0	4	12	12	4	32	3.50
October 30	0	0	2	5	2	9	4.00
November 12	0	0	6	11	8	25	4.08
8. Campbell: Ohio-Osage Field Study	0	1	19	23	11	54	3.81
October 29	0	1	9	12	6	28	3.82
October 30	0	0	1	4	1	6	4.00
November 12	0	0	9	7	4	20	3.75
9. Core Exhibits	0	0	6	31	18	55	4.22
October 29	0	0	5	16	7	28	4.07
October 30	0	0	0	5	2	7	4.29
November 12	0	0	1	10	9	20	4.40
10. Computer Demonstrations	1	0	9	21	15	45	4.04
October 29	0	0	5	12	4	21	3.95
October 30	1	0	1	1	2	5	3.60
November 12	0	0	3	8	9	19	4.26

Footnotes based on comments written on the back page:

- Smoking in DoD facilities has been limited since the late 80's. The recent exec. order was to move the cloud of cigarette smoke away from the entrances where the non-smokers would have to "hack" their way through the smoky maze, scrum, huddle, etc.
- *re Northcutt Intro to FDD:* Seems rambling. *re Andrews Paradise field study:* Did better w/ Red Fork study. *re Knapp:* No economics, No explanation of problems. *re Andrews Russell NW field study:* Stick to interpretations - too much talk here on "maybe this, but maybe not..." *overall:* Maybe I'm being a bit harsh on presenters, but I feel they have done, and really can do a better job of this -- Move along, be enthusiastic and don't try to be funny -- State the interpretation and invite discussion.
- *re Riepl Seismic Stratigraphy:* He didn't convince me of the correlation between his amplitude anomaly and Bartlesville sand quality.
- *re Robert summary:* rates a 5 (Great)
- *re Northcutt Bartlesville Regional Overview*: presented fine - regional data is poorest of any workshop.
- *re Northcutt Intro to FDD:* slides good. *re Supplemental Materials:* Need more time allotted - room was full!
- 300 MBO historically & these were the 2 fields chosen to be studied?